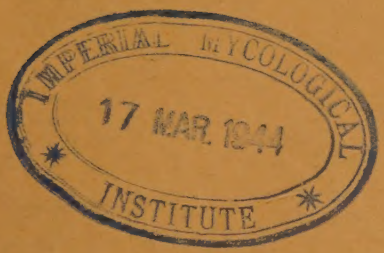
FORESTRY

THE JOURNAL OF THE SOCIETY OF FORESTERS OF GREAT BRITAIN

Edited by H. M. STEVEN

VOLUME XVII



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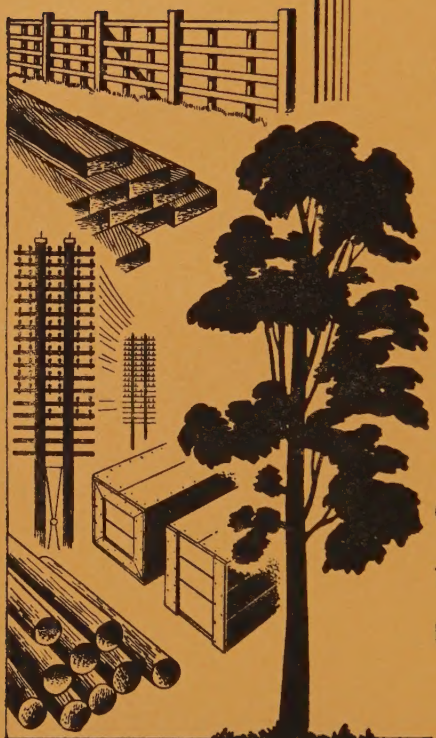

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THE Council has decided for reasons of economy in paper, &c., that *Forestry*, Volume XVII, 1943, shall consist of one Number only.

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SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed in 1925 and adopted its first Constitution at Oxford in 1926. The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects.

The Society consists of Professional and Ordinary Members. Professional membership is divided into two orders:

FELLOWS, being holders of a degree or diploma in forestry, and subjects of the British Crown, but not necessarily resident in Great Britain; and

ASSOCIATES, being subjects of the British Crown resident in Great Britain, whole-time foresters, and not eligible for Fellowship. They pay a less subscription than Fellows but have almost equal privileges.

Ordinary membership is open to persons not eligible for either of the above.

Office-bearers and Councillors are nominated by Professional Members, and in the event of competition for any office a postal ballot of the whole Professional membership is held. The following were elected to serve in 1940:

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THE SOCIETY AND ITS JOURNAL

THE IMPORTANCE OF FORESTRY is being realized more and more in Great Britain. The number of foresters is increasing steadily, and a forestry profession is gradually being built up. It is intended that this Society should be representative of the profession. Those who are not engaged in the practice of forestry or the allied sciences are cordially invited to join the Society as Ordinary Members.

SUBSCRIPTIONS are:

Fellows and Ordinary Members: £1. 1*s*. 0*d*. annually or £10. 10*s*. 0*d*. for Life.

Associates: 10*s*. 6*d*. annually.

THE SOCIETY'S JOURNAL, called *Forestry*, is published twice a year, in June and December. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

CONTRIBUTIONS may be accepted from members and others resident either in Great Britain or abroad. They should be sent to the editor, Professor H. M. Steven, 75 Fountainhall Road, Aberdeen. No article should be submitted which is being offered to any other journal for prior or simultaneous publication. Articles should be typewritten, and must be in a final form suitable for publication. References to literature should be collected at the end of the paper, and arranged alphabetically according to author's name, and numbered. In the text each reference should be indicated by its number enclosed in brackets. Each article should conclude with a summary. It should give the methods, extent of material, observations, and results, but should be brief and not exceed 3 per cent. of the original. It is understood that the author waives any copyright or translation rights in such summaries and that their reproduction in other publications will be permitted, subject to the source being duly acknowledged. Twenty reprints of the article will be sent free to each contributor and a reasonable number may be purchased by the contributor if ordered when the proofs are returned. The Society as a body takes no responsibility for the views expressed by contributors.

Forestry is sent free to members of the Society; others may register as subscribers by application to the Secretary, R. Angus Galloway, 8 Rutland Square, Edinburgh, 1.

SOCIETY'S MEDAL. The Council has resolved that the Society award a Medal from time to time to any individuals who may have rendered eminent services.

POST-WAR FOREST POLICY[1]

W. A. ROBERTSON

(*President of the Society*)

IN both Houses of Parliament the Forestry Commissioners have been complimented on the production of this report, even although the speakers have criticized many of the proposals.

The Introduction of the report opens the subject with a summary of the report of the 'Acland Committee' of 1916–17 which led to the institution of the Forestry Commission in 1919, while the first chapter reviews the history of British forest policy through the last century to 1939. There is no need to dwell on the history of State forestry in this country before 1918, because it is a narrative of committees and commissions successively recommending the plantation of some millions of acres, and of an expenditure by the State of a few thousand pounds to carry out the programme. Against this the Forestry Commission, in the twenty years of its existence from 1919 to 1939, is able to show an acquisition of nearly 655,000 acres of plantable land of which nearly 369,000 acres have been planted, the latter figure representing 75 per cent. of the programme advocated by the 'Acland Committee'. Including Crown woodlands transferred to the Commission, the total estate under its management reached in 1939 the total of 1,144,000 acres, of which 714,000 were classed as plantable. In that period the Commission's gross total expenditure amounted to some £12,428,000, against working receipts of £2,673,000.

While State forestry thus showed definite advance over these twenty years the corresponding record of private forestry is depressing to read. The last war ended with an area of 450,000 acres (estimated) felled or devastated, and since that time only about 126,000 acres were replanted with the help of the Commission's planting grants to private owners. The report ascribes the general failure to replant devastated woodlands to the general environment of the period—social, economic, and political—which it states was not conducive to private forestry. This counter to the admitted criticism that the Commission had failed to give enough encouragement to private forestry during that time does not seem quite convincing. The unofficial reader of the report may feel inclined to ask what the Commission, as fosterer of forestry in all its aspects, did to better that general environment, other than to make planting grants, which in later years were recognized as not being the best means of invigorating private forestry.

Chapter II, which deals with 'The Considerations Basic to British Forest Policy', is an excellent statement of the position of the United Kingdom as regards its need of timber, and the possibility of supplying some at least of that need in peace-time and most of it in war. The 'Acland Committee', on the

[1] Report by H.M. Forestry Commissioners (Comd. 6447), H.M. Stationery Office, 1943.

assumption that the average annual increment would be 70 cubic feet per acre, estimated that a total area of 4¾ million acres of effective woodland should be aimed at to provide a reasonable security in war-time. The Commission consider that in view of increased consumption this acreage should be increased to 5 million, and that even then only 35 per cent. of the current peace-time needs would be *ultimately* covered. How that ultimate objective compares with the pre-war position is shown by the estimate that then home-grown production only covered 4·2 per cent. of the country's needs. From the national standpoint paras. 92 to 116 deserve the closest attention because they bring out most clearly the terrible dependence of this country on imports for its timber supply, with all that that implies in shipping and the defence of sea-routes. After that the report discusses the future of world supplies with commendable caution, for it would be a bold man who would attempt to draw a clear picture. The most one can say is that there will still be plenty of timber left in the world, but whether it will be of the kind that the inhabitants of Great Britain will care to use or readily be able to pay for is another matter. Before leaving the question of supplies the report makes a timely defence of the quality of home-grown timber, if properly grown. In the past home-grown material has been assessed, possibly by interested parties, on its worst samples, with a fine disregard of the fact that the grower must put all his produce on the market here, while the exporter abroad can and does keep his lower quality timber for home consumption, and sends his best to this country.

In paras. 148–95 the Commissioners deal with the area available to provide the 5 million acres of effective forest aimed at. This part of the report suffers from having to depend on very poor statistics, such as the Census of Woodlands of 1924 and the Agricultural Statistics of 1938. Hence the arguments are based on estimates, and although, no doubt, the Commissioners' estimates are likely to be nearer the mark than anyone else's, they do not carry as much conviction as they ought. Professional foresters accustomed to the accurate statistics of the leading continental countries must be surprised that the Forestry Commission has been content with the census of 1924 which was so makeshift an effort. Perhaps more recent statistics could not be published at this time. It is estimated that there will be at the end of the war 3·1 million acres of woodland, or land that has been woodland recently, but of this the report puts aside over one million as being outside the scope of systematic forestry. This is a big proportion to consider as virtually unproductive, and gives the impression that the report is only concerned with 'big business forestry'; *De minimis non curat Rex*? In discussing 'Land for Afforestation' the report makes several good points which might well be rubbed into the critics of the Commission's planting policy, as, for example, that much of the rough grazing-land which might be planted cannot carry hardwood at any rate in the first rotation, that much of it is steadily deteriorating as pasture, and that technical development in planting has increased, and will increase, the proportion of plantable land. The conclusion arrived at is that there is a total of 4·2 million acres of afforestable land in addition to the 2 million mentioned above, so that it will be possible to get the 5 million acres of forest land which the Commissioners have laid down as their aim to have under forest either through State

or private agencies. As to the method by which the land is to be acquired, the report hopes that it will not be necessary to resort to compulsion which has been successfully avoided in the past. The average cost of acquisition has been £3. 16*s*. 5*d*. per acre for purchase, and 2*s*. 9*d*. for lease for the plantable land, excluding land and buildings for forest workers only.

With the probable increase of acquisition of land by other departments of the Government the question of the allotment of land to forestry may become controversial, and the institution of some independent body to decide the question is advocated. This seems to be essential if a proper balance between agriculture and forestry is to be maintained, and to protect the private landowner from being crushed out of existence between the collision of competing departments. The same body is likely to have a thorny path to tread in deciding between the claims of forestry and hill pasturage. Part of the data are given in a separate Appendix, and the conclusions of the Commission's own inquiry is given in the body of the report. These may be summarized as showing that plantable land produces 12·38 lb. of mutton and 3·25 lb. of wool per acre per annum, as against 1½ tons of timber, and that, therefore, the planting of one million acres would reduce the percentage of home-grown to total mutton consumption from 43·2 per cent. to 42·3 per cent. and reduce the tonnage of home-grown wool by 1,450 tons. An aspect of this question which one would have liked to see discussed is the amount of employment which is given by these two systems of land utilization. It would look as if forestry would give a considerably higher figure than pasture. The Government report on Hill Pastures has not yet been published, so that it is impossible to get a full picture of what the transfer from pasture to forest would mean. There is little doubt that there will be much controversy, more especially as there are no statistics to guide an estimate of the employment which will follow on the achievement of the 5-million acre scheme. The report quotes the German statistics and some figures from individual blocks of forest in this country.

The paragraphs dealing with housing are most interesting in view of the Commission's success in establishing workers' holdings, which it assesses at 78 per cent. of the 1,500 holdings established by it. While the net return on the capital invested by the Commission is only 0·4 per cent., the report rightly points out that in view of the need for forest labour the loss must be carried by the afforestation scheme as a whole. On the general social side an experiment which has provided the forest workers with the means to build up a capital in live stock of £50,000 in twenty years cannot be termed only a partial success. The magnitude of the housing problem for forest workers is shown by the existing shortage of 2,000 houses and an estimated requirement of 12,000 for the whole afforestation programme.

Paras. 228 to 247 deal with the much discussed question 'Does forestry pay?', and once again we are left in doubt; that is to say, in doubt as to the exact money return to be expected. Since every professional forester knows that calculations can be produced to demonstrate that forestry can never pay, or alternatively can give a twenty-five-fold return in almost as many years, any juggling with rates of interest and so forth seems rather academic. It is known that even indifferently

managed forests in this country can yield a net income of from 10*s*. to 14*s*. per acre per annum once the forest is established; the value of forests as a long-term national investment seems, therefore, incontestable. On top of this can be added the national insurance value, and the steady employment, both direct and indirect, which cannot be reckoned in cash, but can be judged from the experience of the last few years.

The paragraphs dealing with the same subject from the private woodland owners' point of view touch the more obvious considerations but do not really go to the root of the matter, the uncertainty of the State's land policy, whether as to tenure or taxation. Mention is made of this in para. 238, but, as elsewhere in the report, the Commissioners appear to think that it is not their duty to point out to the Chancellor of the Exchequer exactly where his predecessors have gone wrong in relation to private forestry. Surely this is part of the Commission's duty to foster all aspects of forestry, and its position as an almost autonomous body should relieve it, to some extent, of the shackles of inter-departmental etiquette. In the discussion of the factors influencing private forestry as an investment one notes a curious omission to point out the disastrous results in the past of haphazard exploitation and marketing, and the need of co-operation amongst private owners in the future, more especially in the undefined class of small woodland owners. An indication of how the proposed State afforestation scheme would co-operate with private owners would have been most welcome. The private investor in forestry will naturally want to know where he is going to find himself in relation to State 'big business' in forestry.

Chapter III, 'Private Woodlands', is in many ways the most interesting part of the report. To the professional forester the parts of the report dealing with State forestry are largely the commonplaces of his trade. This part deals with that forestry which has given the country by far the largest part of its home-grown timber supply both in the last war and in this. Upon private forestry there are two schools of thought: one, that the State only needs to exhibit the 'vulture complex', and sit by the dying beast of private forestry until the latter has so decomposed that the State can absorb it; the other, that properly run private forestry can provide timber to the country as, if not more, cheaply than any other agency. This chapter gives the impression of an attempt to take a middle course, but perhaps rather on the side of the vultures. On the grounds of public expediency the report's contentions are incontestable. It predicates, and rightly, that at the end of the war most of the private forests will have been so heavily cut over that complete rehabilitation, in fact reafforestation, will be needed, and that this must be done without delay. No forester will contest this. To achieve this the report gives two alternatives, roughly, that the owners do it with very brief delay or hand it over to the State to do it. This again is reasonable. What the report does not point out is that the owner has been compelled to realize his forest capital at a valuation fixed by the State through its system of fixed prices for standing timber, and is left to carry out the rehabilitation of his forest capital at rates which will not be fixed, and out of a cash capital which has been severely cut down by taxation.

The Commission arrives at another conclusion: that all planting and successful natural regeneration must be looked after until it is safely established. With this all foresters will agree, and with the final conclusion that if the private owner cannot carry out these operations the State ought to do it. From this point onwards many landowners and some foresters will feel that the report bears too heavily against the woodland owner. For instance, under 'Post-Establishment Problems' it concludes that the war-time system of felling licences must continue. This point is the subject of a reservation by one of the members signing the report who disagrees with the proposal. While the argument that the only means of conserving a remnant of standing timber as a reserve is to limit its felling is perfectly sound, it hardly seems fair to forbid the private owner the means of raising cash from his standing trees, and at the same time insist that he must make good the depredations of war or be expropriated. This seems to be 'one-way traffic' in favour of the State with a vengeance. Under the same head the statement that some degree of control over the silviculture of private woodlands is necessary is also perfectly sound; but the question is how much, and the rest of the chapter is not very enlightening on this point.

The 'concrete proposals' put forward by the report are in essence what several landowners and most professional foresters have seen to be inevitable if private forestry is to play its proper part in the national economy. Briefly summed up, they are that woodlands shall be set aside virtually in perpetuity for the production of timber, and that the State will help the owner to grow the timber provided he grows it properly. This setting aside the report calls 'dedication', and as the word has the sanction of all the Empire Forestry Conferences in its present application, foresters can hardly cavil at it. 'Dedication' includes the following undertakings on the part of the owner: (1) 'To use the land in such a way that timber production is the main object; (2) To work to a plan to be approved by the Forest Authority which would lay down the main operations to be undertaken; (3) To employ skilled supervision; (4) To keep adequate accounts.' These principles appear in the forest legislation of every country in Europe which realizes the importance of scientific forestry, and are the only basis for sound private forestry. In substance they are accepted by the forestry and landowners' societies of this country. The only comment one has to make is, why hide the State under the title 'Forest Authority'? The iron hand is there however delicately the glove may be embroidered. In the paragraphs dealing with the 'dedication procedure' there seems to be some ambiguity as to the position of the landowner. As far as one can make out, the Forest Authority, let us call it the State and be done with it, is to decide what areas ought to be dedicated and tell the landowner to dedicate or get out, because if he does not dedicate, they are to pass over to the State. In other words, the landowner must manage his forests as directed by the State or hand them over to the State. From the point of view of forest policy these proposals are perfectly justifiable, but there is very little left of the voluntary principle in the procedure. It is, therefore, a little difficult to see what point there is in discussing the 'Area of Effective Woodland which will be brought under systematic woodland as a result of our proposals',

because the answer seems to be, as much of the total woodlands as the State chooses.

Passing on to the forms of State assistance which might be given in return for dedication, the Commissioners wisely propose that it should not only cover the first stage of rehabilitation, but also the second of securing continuous systematic management. It was the lack of this stage which vitiated the whole of the old system of grants to forestry. Put briefly, the proposed scheme would pay the dedicating landowner 25 per cent. of the net annual expenditure on his forest. How far this is fair to the landowner it is almost impossible to judge at present. It looks as if its practicability will turn on the gross total which the landowner will have to find to bring his woods into order. While the scheme further proposes to provide the landowner with loans at current rates of interest, there must obviously be a vast difference between the position of the landowner who, having had most of his woodlands in a condition suitable for felling during the war, has lost most of his growing stock, and the one who for one reason or another has escaped the slaughter, and has relatively little to rehabilitate. The whole subject of State assistance is one which will have to be thrashed out by the organizations representing the landowners and the State. Whatever proposals the State may put forward, the State ought clearly to recognize that the forest finance of the private estate has been completely upset by the war-time fellings. The nation as a whole has benefited by this wholesale realization of forest capital which the private owner had accumulated, for lack of which the nation's war effort would have been in great difficulties. If the special nature of forest finance is not recognized by the State in the course of these discussions serious injustice may be done, and most probably to those who have striven best to manage their woodlands properly.

Earlier in this review the subject of Small Woods was mentioned. In paras. 294 and 295 of the report the subject is again touched on, very briefly, and, one feels bound to say, very inadequately. No attempt is made to estimate the minimum acreage which can be considered an economic unit. Is it that the Commission do not want to be involved in a forest 'sorites'? The problem of the small wood is one which affects the general public, for it is just these small woods, copses, and spinneys which give so much character to the landscape. They have a definite part to play in the agricultural economy, and might well have a larger. Individually they are no doubt financially uneconomical in the strict sense, but collectively they contributed substantially to the nation's stock of timber, as anyone can see to-day. One would have liked to have seen foreshadowed at least some proposals to foster co-operation between the owners of these small parcels so that more use can be made of the odd corners of waste agricultural land, which might grow some trees at least, instead of being left to grow scrub and harbour vermin.

When it comes to the discussion of the Taxation of Woodlands the report gives a balanced view of the subject, though the subject of death duties does not get sufficient emphasis. Para. 314 says 'one effect of high taxation is that the woodland owner may regard his timber as a convenient asset which can be realised for the purpose of enabling him to meet his taxation liabilities, in particular the

liability for Death Duties on his landed property . . . . From a forestry point of view the position is obviously unsatisfactory.' This is patent to every forester, and until the problem of death duties on the mixed agricultural and forest estate is solved forestry for the private owner, as compared with the State or the corporate owner, will always be in a bad way. The report evades the real issue by saying lower down 'This is a subject which lies outside our purview'. Why? As an almost autonomous body containing *ex hypothesi* the bulk of the forest technicians in the country it should be one of its duties to advise the country how such a problem might be tackled.

The omission to do so detracts much from the discussion on the Marketing of Forest Produce which occupies the succeeding paragraphs. It is well known that much of the unsatisfactory state of pre-war marketing was due to the uncertainty and irregularity of supplies, and for this the incidence of death duties on mixed estates is responsible. The whole secret of successful marketing is the prospect of regular supplies of even quality in the respective classes of produce. Given this, the bogy of bad prices for home-grown timber will almost disappear. No doubt the gradual establishment of large blocks of properly managed State forests will regularize supplies, but not sufficiently if the private owner is obliged to throw suddenly large blocks of timber on the market. It may be contended that the management prescribed for private forests under the dedication scheme will prevent this by force of law. If so, the unfortunate private owner is going to find himself between the devil of death duties and the deep sea of dedication. Not a cheerful prospect for him.

The report also deals with the difficult problem of the disposal of thinnings, and wisely does not attempt to go into details, for the matter is highly technical. As with most other sides of forest exploitation, it is a question of transport costs, though in the past it has been made specially difficult by the privileged position held by the importer from overseas countries.

The possibility of developing new industries which could absorb the large expected out-turn of thinnings is touched on, but those who have had to look into the matter from the technical side will be very cautious in holding out great hopes. Much very careful planning of planting, layout of extraction routes, and choice of species will be needed to build up new industries.

Chapter IV on 'Technical Services' gives a brief summary of what has been done by the Commission, both in operation and in research, but from having perforce to be heavily condensed it hardly does justice to what really has been achieved. An average expenditure on research of 1·7 per cent. of the Commission's total expenditure is a somewhat small proportion in view of the leeway to be made up.

National Forest Parks and the claims of amenity are the subject of Chapter V, and the Commission has done well so far as it has been able to go. It will always be difficult to steer calmly between the nation's need for intensive timber production and the claims of those who can admire nothing but an assembly of trees exhibiting every known defect and disease, and, though they demand the finest animals, grain, and fruit in the world, can see nothing in a well-grown crop of

trees. Anything that the Commission or private owners can do to make the public appreciate all aspects of forestry is all to the good.

Proposals for future policy come in Chapter VI. Starting with the ultimate aim of 5 million acres of effective forest, the proposed allocation of major works is 1,100,000 acres in the first 10 years, 1,500,000 in the second, 850,000 in the third, 700,000 in the fourth, and 500,000 in the fifth. The idea behind the very large allocations in the first two decades is to get the building up of reserves of timber well under way for national safety. This is undoubtedly the right view to take, but whether it can be worked up to, even if both State and private owners go up to the limit of forest labour, seems rather doubtful. Another sound reason for the decrease in the last three periods is that by then thinnings will be beginning to pile up. It is often forgotten in long-range planting programmes that thinnings accumulate in snowball fashion.

Naturally, the programme for the first 10 years is of chief present interest, and two alternatives are given, both starting with 35,000 acres in the first year but one, 'the Desirable Programme', rising to 150,000 acres per annum for the seventh and succeeding years, with the second or 'Intermediate Programme' only reaching 107 in the sixth and succeeding years. The second programme looks like a sop to the Treasury, which might be frightened at an estimated outlay of a net 41·2 million pounds for the first decade as against 32 millions for the 'Intermediate Programme'. The professional forester, accustomed to think 60 or 100 years ahead and picturing the country's need for wood products in all forms at the end of such a period, will regret the suggestion that the 'Intermediate Programme' might be enough for the country. It looks like a false economy. Still, either programme is a bold advance on pre-war ideas. The problem of financing either of the programmes is a serious one. The success of any scheme to give the country its right proportion of land under forest depends on the steady supply of funds, year in, year out. As it has been, the history of forestry in the British Commonwealth on the financial side has resembled too closely that of Mother Hubbard's Dog. Very rarely has the old lady given him 'white wine and red'—mostly it has been 'the cupboard was bare'. In that tale, it will be remembered, when she did come back with some bread 'the poor dog was dead'. This time we will hope that she will feed the faithful hound, and those who get the crumbs under the table, the private owners, will do so regularly. Perhaps in the long run forest finance serves a useful purpose, as the flea on the dog; it keeps the forester in touch with the outside world: but naturally the most interesting point to him in the report is the last chapter on 'The Future Administration of Forestry', for that is where he comes really into the picture. The report lays down five essentials. First, *the recognition by Government of the importance of timber production at home.* This is too obvious to need comment. Second, *a continuity of National Policy including finance.* Third, *an ad hoc Forest Authority with the main duties of formulating policy for the Government and ensuring that the approved policy is carried out.* The other two are a Unified Forest Service and provision for Research, Education, and Information, and are predicated as being dependent on the third. The report gives as its considered opinion that

there should be a single Forest Authority for Great Britain, namely, a Forestry Commission independent of Agriculture. The report goes on to describe the main details of the present organization of the Commission and its future constitution. For the future, the report advocates the retention of the Commission practically in its present form with a committee to deal with private forests, and the institution of separate staffs to deal with State and private forests. These proposals seem to be the most arguable of the whole report. They mean the retention of a virtually autonomous body responsible to no Minister, nor to anyone except Parliament as a whole, and then only in respect of finance. In the past this state of affairs may not have mattered much to anyone, since the Commission was only concerned with its own property of slightly over one million acres. For the future, control over five times that area is contemplated, of which a considerable proportion will be, nominally at any rate, private property. This raises serious questions. It would appear that legislative sanction is to be given to a body the selection of whose members is undefined, which is to wield what amounts to confiscatory powers, against whom there appears to be no power of appeal except through the courts, and for whose actions no one in Parliament can be held responsible. Does such a body exist anywhere in the British Commonwealth? Even to the most out-and-out advocate of forestry the proposal sounds rather too far-reaching. If, as ought to happen, the reorganization of forestry in this country is to bring about so much new employment, new industry, and increased security for the nation, there should be a case for a Minister directly responsible to Parliament to take charge of such an important part of the nation's future prosperity. Also it should be a Minister who can devote his whole time to the job and not divide it up among a number of odd activities of Government, as suggested in the report as an alternative to the present arrangement. Another point which must strike an unofficial reader of the report is that no mention is made as to the authority which selects and appoints the Commissioners, either under the present régime or in the future. One gets the impression that besides being autocephalous the Commission is autogenic.

For the future administration of the State forests the report proposes to form committees of the Commissioners to deal with the three regions of England, Wales, and Scotland, and to appoint a commissioner for each of these regions for executive purposes. This presumably means that each committee will have a technical commissioner attached to it. This is probably a wise step, as it will give each region technical advice more closely related to regional needs than at present.

To look after 'Private Woodlands' a special committee of the Commission is proposed, while the present executive officers (the Divisional Officers) are to have separate staffs, one for State forests and one for private woodlands. Reading between the lines it appears that these officers, whose title is to be changed to Conservators, are to exercise directly the proposed new powers of the Commission over private woodlands.

As the growers of timber, or in the words of the report (see para. 555) 'certain interests connected with the growing and utilisation of timber', are not to be represented as of right on the Commission of the future, it seems that the private

woodland owner may find himself entirely under the control of the State, and required, without right of appeal, to manage his woodlands entirely as the State may direct. He is apparently to be unable to influence the policy of the Commission, either directly by membership of it or through Parliament, except when its budget is discussed. Somehow this looks like the totalitarianism which we are supposed to be fighting. It is indeed surprising to find no mention of the systems of relation between State and private owners which have proved so successful in Scandinavia. It is true that in para. 548 it is proposed that there should be small *Advisory* Committees on which woodland owners should be represented, but the history of the advisory committees which are nominally still in existence gives small comfort to the woodland owner. An adviser only functions when he is asked to advise, he can do nothing *proprio motu.*

Space does not allow of more than passing reference to the appendices to the report, but the figures for the average volume per acre for this country for a number of species, and the comparison of it for two species with that of Prussia, Sweden, and South Finland, shows clearly that Great Britain enjoys a decided advantage in rate of growth.

In concluding this review, the writer's opinion is that the report is a most valuable one, and, by reason of the experience gained by the Commission in the last twenty years, quite the best which has yet appeared. It brings out clearly the country's need of forests, and shows how these needs can be met in part at least by State agency, which has increased the forest resources in the last 20 years. Few foresters will find much to criticize in the proposals for the continuation of afforestation by the State and its extension. When it comes to private forestry the report hardly does justice to the subject, and certainly does not give credit to those owners who, in spite of many difficulties and discouragements, have kept an invaluable stock of timber alive against the present emergency. The reviewer feels that the Commissioners must have discussed the fate of the private owner from the same angle as that from which an august conclave, reported by Anatole France, debated the fate of the penguins, and decided 'There is only one solution, the penguins must go to hell'. Need the private woodland owners really be sent there?

ECOLOGICAL PRINCIPLES INVOLVED IN THE PRACTICE OF FORESTRY

A REPORT of a joint meeting, organized by the British Ecological Society, following the publication by Sir Roy Robinson in *Forestry* XVI of an article entitled 'Some Ecological Aspects of Afforestation and Forestry in Great Britain', and held in London on 2 July 1943. The Chairman was Captain C. Diver, and the meeting was attended by members of the British Ecological Society, of the Society of Foresters, and other forestry societies in Great Britain. The Report has been prepared by Mr. L. A. Harvey for the *Journal of Ecology* and is published in *Forestry* by his kind permission and that of the British Ecological Society.

PROFESSOR A. G. TANSLEY, F.R.S.

First of all I must warmly welcome the desire of the Forestry Commission, as recently expressed by its Chairman, to make closer contact with ecology. And on behalf of the British Ecological Society, whose President, as we must all regret, is unfortunately prevented by illness from taking the Chair to-day, I am sure I can reciprocate that desire. For not only can foresters find in ecological work much that will help them to a scientific rationale of their practical operations: ecologists can find in the results of those operations, whether successful or unsuccessful, invaluable material for learning more about the reactions of growing trees to different conditions. Every plantation is an ecological experiment, and on a scale which working ecologists rarely have the opportunity to employ.

Scientific ecology, we must remember, is a very young subject of research, almost entirely a product of the present century, and only developed energetically since the last war. It has had many difficulties to face, though to-day, I am glad to say, its influence is rapidly extending. Not the least of its difficulties has been the lack of sufficiently extensive opportunities for adequate ecological experiments, without which the science cannot progress. I know very little of practical forestry, and I have often wished when I was teaching forestry students their elementary botany, and always from the general point of view of ecology, that I had had a practical training both in forestry and agriculture, just as I wished I had had a practical training in medicine when I was teaching biology to medical students. For just as scientific medicine is really a branch of applied biology, so forestry and agriculture may be regarded as branches of applied ecology. But the practical arts of medicine and agriculture are much older than the corresponding branches of pure science—agriculture some thousands of years, forestry in Britain two or three centuries, while ecology is a growth, so to speak, of yesterday. Consequently a great deal of largely empirical knowledge has been accumulated, while ecology is only now beginning to be in a position to attempt explanations of some of the facts observed. What we need above everything to increase our knowledge of the ecology of woodlands is, as I have already insisted,

continuous opportunity for access to and study of planting experiments, together with the power of suggesting different variations and forms of control which seem likely to lead to increased insight into the factors at work. This line of thought clearly envisages a very close collaboration between foresters and ecologists.

The Forestry Commission has itself conducted many planting experiments and studies of tree growth intended to throw light on the practical difficulties it has encountered. In a broad sense such work is ecological work, but it is, of course, designed, and must be designed, to solve specific practical problems rather than to arrive at new scientific generalizations that can be used to guide future developments. Exactly the same distinction exists in industry, where technological research is necessary for the solution of specific industrial problems, while pure research in the basic sciences, conducted with the aim of increasing scientific knowledge, forms the foundation for new general advances. That is not to say that practical problems cannot provide starting-points for pure research. On the contrary they can, and constantly do. Rayner's work on mycorrhiza and Neilson Jones's on the toxicity of Bagshot Sand soils at Wareham, where pine obstinately failed to make good growth, are examples of research which used practical difficulties as starting-points, though Rayner's contributions to our knowledge of mycorrhiza were begun at a much earlier date. The point is that research in pure science must be free to be pursued wherever it may lead. It may or may not immediately throw direct light on current practical problems. When it does, the whole subject is more brightly and widely illuminated because the research is not narrowly tied to a particular problem. Both kinds of research are necessary, and it is only by the combination of the two that the most fruitful progress is made.

Sir Roy Robinson has put forward two working hypotheses which he calls the hypothesis of *accelerated succession* and the hypothesis of the *silvicultural stream*. Both are based on the general theory of the succession of vegetation which is one of the cardinal theories of plant ecology.

The hypothesis of accelerated succession states that

'in the natural afforestation of difficult sites some species are pioneers and some are successors. It is not feasible by artificial means to bring in the successors in advance of the pioneers. It is possible, however, to accelerate the natural succession by mixed planting of pioneers and successors, and by appropriate thinning treatment to complete the succession in the course of a single rotation. A successor on one site may be a pioneer on another.'

It is not only on 'difficult sites' that there is a regular succession of vegetation in 'natural afforestation' and a typical sequence of pioneers and successors among the species colonizing the site. That is a universal phenomenon following constant general laws, though the details are exceedingly various according to the nature of the climate and soil and the species available for colonization. The complete sequence begins with a bare site unoccupied by vegetation, and trees rarely figure among the pioneer plants, though they may sometimes do so, as on wet alluvium newly laid down by a river. But the vast majority of bare sites are, to begin with, difficult or impossible for trees, which cannot succeed until a soil

has been created on a bare rock surface, or a raw soil mixed with the humus left by the pioneer plants. Even when trees do appear, some species come before others because they can tolerate relatively unfavourable conditions, and also often because their parents produced abundance of seed easily transported to the site in large quantities. These pioneer trees, of which birch and pine are good examples in this country, ultimately give way to heavy-seeded, more exacting, and shade-bearing trees, usually of slower growth, such as beech and spruce, which eventually overshadow and kill out the light-demanding pioneers. Among the successors some become dominant and form the so-called 'climax forest' natural to the region. But because they are more exacting in their demands upon the soil they only succeed on soils which are capable of meeting those demands. Thus among the natural spruce forests of central Sweden there are areas of shallow soil, overlying flattish rock surfaces, which are occupied by pine, with no spruce, because the soil has not developed to meet the demands of spruce. Pine (with birch) is a natural pioneer, preceding spruce in these forests, but when spruce, the climax dominant, comes in and can flourish, pine is naturally eliminated. On the areas referred to pine takes the place of the climax dominant and forms what ecologists call a 'subclimax'. As Sir Roy Robinson points out, we are still largely ignorant of the exact factors which prepare the way for successors or climax dominants, though we know something about them in a general way. Almost certainly they differ in detail in different cases, but as he shows, there is good evidence that the earlier colonists often promote, directly or indirectly, the success of the later ones. Hence the practice of mixed planting which artificially brings these beneficial effects into operation.

The 'good' sites for planting are those in which the soil is well developed, well provided with available nutrient salts, well aerated, and retaining a sufficient supply of the right kind of humus, as on good old pasture grassland or good arable land. Here we have conditions corresponding with a *late* stage of succession, and exacting trees can be planted at once. The 'difficult' sites are those in which previous treatment of the land has reduced it to conditions corresponding with an *early* stage of natural succession, in which some or all of the favourable factors mentioned above are absent and climax trees will not succeed without preparation. The two types of difficult sites chosen by Sir Roy as examples are, first, those comparatively well-drained soils of the old acidic rocks and some of the more recent sands on which heather quickly develops as the result of enclosure and cessation of grazing or burning, and secondly the shallow chalk soils of the south and east of England. On the first type the soil is typically poor in nutrient salts and on the second it is shallow and dry, with insufficient humus.

The procedure suggested by Sir Roy—'mixed planting of pioneers and successors'—brings about a condition comparable with that obtaining in what is sometimes called 'telescoped succession', i.e. natural succession in which two or more species of tree, including pioneers and successors, sow themselves on a site at about the same time. The quicker growing pioneers, which are better suited by the soil in its undeveloped state, become dominant first, though both start at the same time, and later the slower growing successors, favoured by the shelter of the

pioneers and/or by changes brought about in the soil by the vegetation cover, grow up among the pioneers and eventually suppress them and become dominant. Alone they could not have done so. It is clear that mixed planting of pioneers and successors in suitable, empirically determined proportions, imitates this natural process, and should result in a successful crop of the successor tree which is desired.

Sir Roy's first example is Scots pine and Douglas fir in Swaffham Forest. A similar example he gives is in the New Forest, where Douglas, common ('Norway') spruce, and Sitka spruce did not succeed on heather areas until Scots pine had reseeded the ground from adjacent trees. Ecologists have long been very familiar with the ability of Scots pine to grow up among thick heather and eventually to convert a heather area into a pinewood. I remember, many years ago, making a count of pine seedlings among thick heather on a common on the borders of Surrey and Kent, and finding an average of one seedling to every square yard. These came from a mature pinewood about 100 yards away. Some of the seedlings were smothered by the heather, but many came through, and the common was dotted with vigorous pine seedlings and saplings of all ages. During the last war all the pine was felled, and some years later the area was covered with dense young birchwood—birch being the other pioneer tree on such soils—owing to the drastic diminution of the pine seed-parents. Oak and beech were present on the site and were actually dominant on neighbouring areas, but whether they would eventually have followed pine on this particular area could not be determined because of constant disturbance by such factors as rabbit attack, grazing, and gravel digging. This perpetual interference is one of the greatest handicaps of ecologists in determining the natural course of succession in native British woodlands.

Other examples given by Sir Roy are on the old acidic rocks of the hill country of the west and north. In one of these the planting of pine not only enabled interplanted spruce to succeed but extended its favourable influence to two or three adjacent rows of pure spruce. Here we are faced with the question, in a particularly striking form, of what exactly are the ecological factors through which pine affects spruce. Ecologists have been largely occupied hitherto in describing the facts of natural succession, but we can have no thorough knowledge of a succession until we have discovered the actual effective factors which enable one kind of tree to succeed in the presence of another but not alone. In some cases, part at least of the effect seems obvious enough, but in others it is still unexplained. Only carefully designed experiments will discover the actual factors at work, and this is essentially the business of the ecologist. It is clear, I think, that successful work of this kind would be of great use to the practical forester because it would enable him to direct his planting on the secure foundation of adequate knowledge of the factors involved, and not merely by empirical results the causes of which he does not understand.

The other type of difficult site discussed by Sir Roy is chalk down. Here the natural forest trees are ash and beech, and it has been shown by Dr. Watt, in his exhaustive studies of natural succession in the Goodwood region and on the

Chilterns that ash precedes beech on the shallow chalk soils proper, while ash and oak precede beech on the deeper loam soils of the chalk plateaux. In both cases the trees are normally preceded by a scrub phase, of juniper, hawthorn, and other shrubs, the scrub providing the conditions in which the trees can succeed. The Forestry Commission has found that not only Scots, Corsican, and Austrian pine, but also Norway spruce, will act as an effective 'nurse' for ash and beech on such sites. This is an unexpected example of a tree which is the dominant of climax forest in its own climatic region acting as an effective pioneer when planted in quite different conditions.

Sir Roy Robinson's second working hypothesis is that

'in the silvicultural treatment of woodlands the most effective methods are those which proceed in the direction of a natural succession of vegetation.'

The concept of a 'silvicultural stream' thus postulated is an example of following intelligently the processes of Nature and adapting them to human requirements. In other words, we have to learn to understand Nature before we can effectively control her. I entirely agree with Sir Roy's suggestion that, in undertaking silvicultural work, the point of entry into the natural scheme of succession and the direction of flow should first be determined, and that here is a field of ecological research which should prove useful to the forester. In the case of our native woodlands the phases of most successions are already well known in outline as the result of ecological work during the past twenty-five years. But we have to recognize that the Forestry Commission is mainly dealing with exotic trees, and that the actual requirements of these, and consequently the places they can be made to take in an artificial silvicultural succession, are still very incompletely understood. I suggest that ecologists should make separate studies of the chief important species of exotic conifers used by the Commission, e.g. Japanese larch, Corsican and Mountain pines, Douglas fir, Sitka and Norway spruce, *Thuja plicata*, and *Tsuga heterophylla*, their behaviour under different British conditions of climate and soil, and their relations to other species with which they may be planted or sown. Such studies should be entirely free, i.e. they should be directed to learning as much as possible about the life and behaviour of each species rather than to the solution of any particular practical problem. In this way facts may be demonstrated which may ultimately prove of crucial value to practical forestry but which may be overlooked if the investigations are narrowly circumscribed. But there would be every reason to choose first of all those species which are of most importance to British forestry and in the case of which practical difficulties have arisen because of defects in our knowledge.

In regard to the 'silvicultural stream' I may repeat what I have already said, that the crucial point for research is discovery of the actual factors which enable one tree to succeed only in the presence of another species, or, to put the point more generally, of the intimate nature of the processes which lead from one phase of succession to the next. Sir Roy Robinson alludes to this when he writes of 'the way in which the pioneer prepares the way for the successor species'.

These two lines of inquiry, then, I offer as suggestions of the ways in which

ecologists can give the greatest help to forestry, and I very much hope the Commission will see its way to make them possible. I expect a new development of activity in ecology after the end of the present war, comparable with, but greater than, that which occurred after the last war. To give such a development adequate scope ecologists need wider opportunities and, of course, the means of livelihood. The ability and enthusiasm are there all right, as has been abundantly proved by the ecological work of the last twenty-five years.

One other topic I should like to refer to before I sit down. The British Ecological Society will shortly publish a Report on Nature Conservation. In this will be found some discussion of the possible role of the Forestry Commission in this important matter. It is no use disguising the fact that widespread alarm has been aroused by the great scheme of afforestation designed by the Commission for the post-war period. This is mainly because conifers greatly preponderate in the planting programme, and conifer planting on a large scale in the English lowlands will entirely alter the character of the English landscape, which depends to a very great degree, especially in the southern counties, on the presence of deciduous woodland. This alarm is shared by ecologists, who are deeply interested in the continued existence of woodland composed of our native trees such as oak, beech, ash, birch, and alder. Descendants of our original native forests, more or less modified and more or less replanted, still exist in many places growing on their natural characteristic soils, and they form an important part of the primary material available for ecological work. It is, therefore, an outstanding interest of the British Ecological Society that at least extensive samples of these woodlands should be preserved.

Two facts, essentially relevant to this question, are clearly recognized by the Society. The first is that very many of these woods are in a deplorable condition from the forestry point of view and that many also have been depleted by war-time demands. A considerable proportion have been neglected and often badly maltreated in the past owing to a variety of causes. Some at least could, however, be brought into good condition under proper management and with judicious planting here and there so that they could eventually be exploitable for timber. Those quite depleted must of course be replanted. We desire to see at least considerable parts of these deciduous woods maintained as such and not replanted with conifers. If the Commission were to see its way to work on such lines it could make a very significant contribution to the conservation of nature in the English landscape, more particularly perhaps in the south-eastern counties, whose climate is essentially a climate of deciduous forest and which at present have a far larger proportion of their areas under this type of woodland than has any other part of the country. We feel that the Commission bears a great responsibility in this matter.

The other relevant fact to which I alluded is that the demand which the Forestry Commission has to meet is mainly a demand for softwood, i.e. coniferous timber, and it is of no use for us to stop at telling them that deciduous woodland ought to be preserved when the main object must be the production of coniferous forest. At this point we suggest, as ecologists, that there are two areas in which

coniferous forest is ecologically in place. One is the 'highland region' of the north and west of Great Britain, not the so-called Scottish Highlands alone, but the whole region of older rocks known to geographers as the 'highland region'. The other is the heathland of the sandy soils scattered through the English lowlands. In the highland region both climate and soil are relatively unsuited and often impossible for agriculture, and the region is now occupied mainly by moorland and hill grassland. It is, however, a prehistorical accident, so to speak, that this region has contained no native coniferous tree except the Scots pine in post-glacial times, and there is no ecological reason why we should not now supply the deficiency in response to the demand for coniferous wood. This indeed the Commission is already doing on a fairly large scale, but we suggest that a comprehensive scheme should be extended over the whole 'highland region', which would of course involve an overriding right to use the land for national purposes. The diminution of food and wool (sheep) production would, as the Commission has recently shown, not be very great by planting on hill grassland, and we can certainly no longer afford the great areas of the Scottish Highlands now devoted to deer forest. Here we should like to see great forests of climax conifers developed and allowed to grow to maturity. Such forests might well be things of considerable beauty as well as of high economic value, and they would develop an ecology, a flora and fauna of their own, of the greatest interest to plant and animal ecologists and to all naturalists. At the same time the now scanty remnants of old native oak, pine, and birch woods in the Highland glens should be preserved as they are, and an effort made to induce natural regeneration by excluding grazing animals. Some of the most picturesque moorland and mountain country should of course also be preserved in its present state, but much of this is in fact 'unplantable'.

On the heathland of the English sandy soils, especially in Breckland, the Commission also has large plantations, and there is no doubt that this land is in every way suitable for the growing of conifers. Ecologists would, however, plead for the preservation of some of the best areas of heath in their open state, for example in Breckland itself and on some of the Dorset heaths, because they support an exceptionally interesting flora and fauna which is profoundly modified or destroyed by planting. Agreement on the delimitation of them should not be difficult.

In the concluding pages of his notable paper Sir Roy Robinson remarks that 'it would doubtless be possible to found a whole system of silviculture on the theory of the succession of vegetation. Clearly it would have to be of the nature of a selective system under which single trees or small groups only were felled, because that is the only way in which we can conceive the succession proceeding uninterruptedly'. And again, 'there is room in British silviculture for other methods than clear felling and replanting . . . here there is an opportunity to practise silviculture on lines which have hitherto been neglected'.

This is exactly what ecologists would like to see. A forest developing to maturity on natural lines is an object of the greatest importance for ecological study, while a single crop of conifers, or of any other trees for that matter, is of very limited interest. In the initiation of a new forest which is to be allowed to

develop to maturity mixed planting is no doubt an important technique, and some of the ecological research I have suggested should certainly throw light on the factors involved in the mutual relations of the planted trees. In the later stages of development it might well be possible to obtain natural regeneration as selective felling proceeded. During the whole period ecological study of the development of the trees, of the accompanying plants and animals, and of the soil, should be continuous, and could not but result in important accessions to knowledge.

On the lines I have suggested the Forestry Commission would not only discharge its primary economic task but could help to conserve our native British woodland and at the same time create new forest communities of surpassing interest.

SIR ROY L. ROBINSON.

I am flattered that the Ecological Society should have thought it worth while to pin to-day's discussion on my paper. Particularly do I wish to thank Professor Tansley for the comprehensive and sympathetic manner in which he has opened the proceedings. This is an opportunity for ecologists and foresters to make better contacts, which I trust will produce useful results.

Perhaps you will forgive a personal aside. I am not a botanist, much less an ecologist, and the paper was written by a forester for foresters. It has been my privilege to be in British State forestry from the jump, that is, counting the very tentative beginnings, upwards of thirty years. Some of my friends suggested, too kindly perhaps, that I must have learned something which would be of use to future foresters, and that I ought to write it down. Having regard to the current uncertainty to life there was a case for making a record, but the more I looked at it the less I liked the idea. It seemed in fact that there were more urgent things to do, and that time would not be available for doing what I would want to do.

There was, however, one leading consideration which has gradually forced its way into my mind, namely the necessity of basing British forestry more squarely on Nature. Our first afforestation work was necessarily artificial in its main aspects. We selected and planted trees on the basis of such personal evidence as each of us possessed, confident even in some cases that our mere action was warranty of success. It was not always so, and we had to set to work to find the causes of immediate failures. I do not regret that procedure. It has given us large areas of productive plantations, and it has also forced us to seek solutions to problems which we would not even have tackled had we played wholly for safety. It has also given us a practical view of the value of research and experiment in such an undertaking as large-scale forestry.

The main conclusion at which I arrive in approaching the sere and yellow leaf is that the processes involved in growing timber are far more inter-dependent than I had ever suspected. I am speaking now of the biological and not the physical aspects of managing forests. I take it that these interactions of plants, animals, and insects within the house, which is the forest, are the province of

ecology in its widest sense. Therefore the forester, who has many routine calls on his time and energies, must seek the help of the ecologist.

Coming now to the substance of my own paper, I apologize, as I have already indicated, to your Society for its amateurish layout and at the same time venture to express the hope that you will both subject it to such criticism as it deserves and also, to the extent which you see fit, furnish us foresters with constructive proposals.

It has been suggested that because we seem to be in a fair way to solving the difficulties in establishing plantations on difficult sites we should be content to have achieved the result and not inquire into the reasons why. I feel that that attitude is short-sighted. It is improbable in the first place that we have extracted the last ounce of usefulness even so far as establishment of plantations is concerned, and I feel quite sure that what is useful in the establishment stages may also be found useful in the pole and semi-mature stages of forest crops.

It is possible, too, that by pursuing the ecological problems we shall get unexpected light on other problems. I have in mind particularly the problems of forest soil science. Here the agricultural approach has proved singularly inadequate. We have been groping for a long time to find a better avenue, and if the ecological holds out prospects, as I think it does, then we certainly ought to follow it up. Such an investigation would have to be comprehensive calling for co-ordinated effort by ecologists, soil chemists, and physicists, with the initial emphasis on the ecologists.

There is of course scope for much useful field-work of a general observational character. The pine remnants of the Caledonian Forest present an interesting problem. Portions of it have now been kept relatively free of grazing for a number of years and it is possible that useful information is accruing.

The selective felling amounting often to devastation which our broadleaved woodlands are now undergoing is setting a very difficult reconstruction problem for the forester. Some better way than clear-felling and replanting at prohibitive cost must be found if possible. If we knew clearly the natural development of such areas we should be in a better position to regenerate them.

There is one other problem of general interest to which I would like to refer, namely, mixed as opposed to pure planting on sites other than difficult ones such as those to which my paper refers. Pure plantations are undoubtedly unnatural or at least highly artificial, and we are told that they may well lead to disaster through insects or other causes and lead also to soil exhaustion. It may be so, but we have to remember that some of our pure plantations are producing timber at a very high rate—200 to 250 cu. ft. per acre per annum—which is a vital consideration in view of the necessity of recreating our reserve of standing timber in the shortest possible time. Others tell us that associations of pure conifers of various species will likewise lead to trouble, notwithstanding that the magnificent forests of Western America are predominantly or wholly conifers. According to these authorities the admixture of quite a small proportion of broadleaved trees such as birch or beech will put matters right. It may be so, but apart from the impossibility of getting any broadleaved species to live for any appreciable part

of the rotation in mixture with rapidly growing conifers, I have an uneasy feeling that much of the argument is not based on observed facts which are strictly applicable to British conditions. This is a matter of some importance. If, as seems inevitable, we plant pure on a large scale, we ought at least to begin to provide our successors with the data on which to decide the advisability of turning over to mixed forests on the second rotation.

I look forward to your remarks, and if the Chairman so permits would like to reply to some of the points which may be raised.

PROFESSOR H. G. CHAMPION.

As Steven reminded us in 1930,[1] some at least of the general principles of plant ecology have long been recognized and often acted on in forestry, so that the modern science owes a considerable debt to silviculture. The paper now under consideration focuses our attention on the considerable development of ecological science and the help which might and should now be derived from it in forestry operations.

The ecological approach has been more and more used in Indian forestry during the past 30 years at least, largely in relation to policy with regard to the effects of fire protection on the regeneration of the varied types of forest, sometimes found to be in the directions desired by foresters, but sometimes not. It was more specifically emphasized and expressed by a special committee appointed in 1933 to report[2] on the position in the *sal* (*Shorea robusta*) forests which extend over a tract some 800 miles by 200 miles in northern India. This committee, after extensive inspection and discussion, found that the ecological conditions in these *sal*-bearing forests varied so widely that the consequences of any particular operation carried out in any one of thirteen main types, and probably twenty-one subtypes, could not safely be assumed to be the same in any other, and as with fire protection, were already known to be different. May not something of the sort hold for the oakwoods of Britain? In considering any forest type, the importance of determining its ecological status with regard to climax vegetation, and its dependence for continued existence on controllable factors, was stressed as an essential first step towards sound silvicultural treatment and management. In this connexion the ground flora required as much attention as the trees if any were present. Sir Roy's paper reminds us of the value of existing vegetation as an indication of the potentialities of a site for afforestation, but as Steven and others have pointed out, it is equally important to sound the warning that, owing to the aggressiveness and adaptability of the plant *Calluna*, 'heather ground' may be any of several ecologically very different types with very different potentialities, some intrinsically good, some amenable to treatment, and some very intractable. For *sal*, some forms of grassland provide a closely comparable case.

Sir Roy's first generalized conception of 'accelerated succession', to be intelligently applied in the interests of forestry, postulates that we have knowledge of the normal succession. Sometimes a deduction from established principles may suffice, but often our knowledge is so incomplete that results may be very disap-

[1] *Forestry*, iv (1930) p. 26.

[2] *Indian Forest Records*, xix, pt. iii.

pointing owing to lack of recognition of some influential but less understood factor at work. We require to study, therefore, the natural successions, possibly with varying amounts of manipulation of the site factors, such as drainage and soil working, which are practical possibilities in afforestation; soil and rooting conditions require study equally with the vegetation. The ecological reserves in the establishment of which the preliminary steps have already been taken provide the opportunities for such studies, but there is much work to be undertaken before we have an adequately documented history of the developments which take place on sites of different types. A considerable amount of work on these lines has already been done with *sal* in India in connexion with systematic experimentation on regeneration problems and, as mentioned, very wide differences have been recorded. A comment not out of place on the present occasion is that the work has been almost entirely left to the foresters with too many other duties to carry out, and the botanical ecologists and physiologists are not taking a large enough share of the burden. This I felt impelled to stress to botanists meeting at the Indian Science Congress in 1938, pointing out that the forests, as the climax vegetation of almost the entire subcontinent, had a big but almost unheeded claim on their attention.

Now from a study of the site concerned and our knowledge of general principles of succession with a given flora, we arrive at some conception of the ecological potentialities which constitute Sir Roy's 'silvicultural stream', i.e. the lines on which the vegetation tends to move from its own interactions with the habitat factors. I feel, however, that there is a danger of oversimplification which should be kept in mind and can be illustrated from tropical experience. Just as we are tending to change Darwin's concept of the *origin* of species to the *origins* of species, so here it may be more advisable to bear in mind the probability that the stream may have several channels; it may converge with many others, or it may split up into divergent branches possibly all merging in the end as a delta does in the ocean, but also possibly continuing divergent, or even, as rivers have often done in the past, completely reversing their direction of flow. The course and speed of the stream can certainly be greatly influenced by the introduction or exclusion of such everyday operations as grazing, burning, fire protection, and draining. Turning to ecological terminology, I think I might say that as my own experience of old world tropical forests has grown, I have come to realize how enormously greater has been and is the influence of biological factors on the vegetation than one thinks on first contacts: in Indian forests, it is certainly far more usual to be dealing with a biologically conditioned preclimax than anything else. The deduction from these considerations is once again that to derive such benefit as may be possible from working with the silvicultural stream, we need to know a lot more about the stream, and that as the movements are rather slow, the sooner we start to find out the better. The complications consequent on the introduction of exotics, some of which like Norway spruce might easily have been present in our natural vegetation but for historical and geographical accidents, do indeed increase the uncertainties, but do not greatly alter the general picture.

The claim that operations which move with the silvicultural stream are more

likely to succeed than those which go against it is generally supported by Indian experience. Thus the artificial introduction of the species of the next stage of a succession is more likely to succeed than that of other species of similar requirements to the existing species, or than that of the climax species.

For instance, in the Himalayan forests the position and extent of the transitions from oak to conifer or one conifer to another are considerably altered when the forests are fire-protected and the change to the new equilibrium can be hastened by silvicultural operations facilitating it, e.g. by opening up the oak, its replacement by natural blue pine may be expedited, and similarly for planted deodar.

How much one can expedite matters will depend on local conditions. A good illustration of this is the far more rapid succession on new alluvium under the more favourable climatic conditions of Bengal in contrast to the same succession in the more westerly provinces with a much longer dry season. In the latter, *sal* appears unable to establish itself until a considerable depth of loamy soil has been built up, by which time the original single generation pioneer species (*Dalbergia sissoo*) will have disappeared, whereas in the former *sal* may get established while the *Dalbergia* is still present. There is little doubt that lack of humus and appropriate soil flora and fauna are primarily responsible for initial difficulties on many new alluvial deposits, and the forester must accept the fact that time must elapse before they can carry the more exacting species of later stages in the succession. The pioneer species are possessed of adaptations enabling them to cope with the deficiencies as exemplified by the prevalence of Leguminosae with nitrogen-fixing nodules—as in the *Dalbergia* and *Acacia arabica* of river alluvium, and in the *Casuarina* of coastal sands.

Secondary succession can usually be expedited much more effectively than the primary, but to an extent depending on the degree of deterioration of the site which has occurred. Thus after a new clearing or heavy felling there may be difficulties with the immediate re-establishment of the original climax type, but provided habitat conditions are not permanently changed by the introduction of new factors such as burning or grazing, conditions are rapidly restored when the soil cover is once more complete. Soil inoculation experiments have shown that in some instances, at least, biological factors are directly involved.

In the Bengal *sal* tract it was found that fire protection was sometimes itself adequate to bring about the complete displacement of 'elephant grass' by tree growth (*Macaranga*[1]), but none of the attempts to establish *sal* under or among this pioneer tree growth have succeeded so far. It seems probable that a period must elapse before this becomes possible. Similar difficulties have been experienced in other types of *sal* forest in other provinces.

Again, a less exacting nurse crop may be necessary in felled tropical evergreen forest to get the climax evergreen species re-established, but whether naturally or artificially introduced, this nurse crop can soon be gradually removed, or will in due course be largely crowded out by the climax species. Such appears to be the case with the mixed evergreen forests of India, and the silvicultural practice

[1] *Ind. For. Rec. Silviculture*, I. i, Pl. 20.

developed has been to go with the stream by first providing such a nurse crop and then hastening its disappearance when the time is ripe.[1]

By further development of this conception we might anticipate that secondary successions might sometimes be so rapid ('telescoped') as not to allow adequate time for fullest development of one stage before passing on to the next. This does appear to be the case when we introduce on a cleared forest site a pioneer species, for instance the *Dalbergia* already mentioned on a *sal* area. At first, with plenty of room and light it may grow very vigorously, but long before attaining normal maturity, conditions become unsuitable and it dies out; meanwhile, by the protection it gives to the slower *sal*, it may favour the regeneration of the latter.

One may contrast with this what may happen if species are introduced which belong to communities requiring more favourable conditions of moisture, &c., than are naturally available on the site. Account also has to be taken over the limiting effects of occasional combination of unfavourable factors which may not occur for some years after the introduction. With thorough soil working and other assistance an excellent start may be made and all may go very well indeed until, with advancing age and size, requirements go up and finally cannot be met—with resultant rapid deterioration and ultimate failure. India has several large-scale illustrations of this in the attempted rehabilitation of ravine lands under severe climatic conditions.

Several cases might be specified in which attempts to raise trees in full light have failed, apparently through insect attack, e.g. several of the Meliaceae and *Chlorophora excelsa*. Is this failure due to trying to go against the stream? It may well be so, for these trees in nature tend to come up singly or in groups in shelter or shade of other trees, and there escape severe attack or at least survive, and silvicultural technique has perforce to follow the same lines, adopting mixtures or introduction by scattered underplanting.

Turning to the next problem, the choice among the potentialities of the site under consideration, we come to *the conflict between the naturally occurring and the economically desirable*. Movement with the silvicultural stream, i.e. towards the climax vegetation, may mean movement from an economically profitable to a less profitable or even non-paying type. This is strikingly illustrated by our increasing knowledge of the ecological status of the *sal*- and teak- bearing forests of India. It can be asserted without fear of serious contradiction that over important parts of the existing distribution of these forests they are not climax types; which latter would have little or none of these commercially valuable timbers in them, and instead, would consist mainly of species at present not marketable. Many of our best *sal* forests have almost certainly originated in heavy grassland formed after the clearing of mixed evergreen forest, for cultivation, subsequently abandoned. Parallel illustrations could be drawn from other forest types in India and other parts of the tropics, notably the frequently higher commercial value of the trees of secondary or sub-climatic semi-evergreen or moist deciduous forest compared with those of the climax rain-forest. The significance of this

[1] *Ind. For. Rec. Silviculture*, iii. 4.

fact is that in such forests the forester's problem is to stem the silvicultural stream or perhaps to divert it. There are clear indications that to keep young *sal* plantations healthy in sites too damp for climax *sal* forest, they must be opened out and periodic ground fires must be run through them, season and severity depending on conditions.

Similarly in regeneration operations, expensively bought experience has shown that in moist types drastic steps must be taken to reverse the current at least as far as the ground vegetation is concerned and force it back towards open grass and away from the natural tendency to close evergreen.

We know less about teak, but we are certainly not in the silvicultural stream at all with pure teak plantations, though systematic research work, particularly in Java, goes to show that they are by far the best economic proposition, not forgetting to take into consideration long-term reactions on soil productivity.[1] However, these complications only serve to underline the importance of ecological studies to chart the course of the silvicultural stream and to determine the effect on it of any controllable factors. In so far as the economic objectives lie at points along the main stream or such diversions, silvicultural operations with the current may be undertaken with much greater prospect of success than operations against it and may be expected to increase the velocity of flow.

A further example is available from the Himalayan coniferous forests where, as in Europe, the silver fir is the species best adapted to shade conditions and at certain elevations follows pure blue pine or mixed conifers including blue pine, deodar, and spruce, the natural succession creating conditions in which the pine cannot regenerate as a crop, but only as scattered individuals or groups, whilst the fir is not easy to establish direct. This succession is very liable to be encouraged by normal regeneration operations, but unfortunately the fir is the least valuable species of all and often is either unsaleable or will not cover the costs of extraction.

In conclusion, it appears advisable to refer to the practical difficulty commonly experienced in India and the tropics (as in Britain!) in unconscious attempts to follow the silvicultural stream by planting mixtures. The end results have very generally been poor even where the start was good, but this verdict has been rather from the point of view of timber production than merely vegetative development. Just as the selection system, though perhaps the most 'natural' system, requires much more intensive management than the more artificial systems, so does the mixed plantation, though also more 'natural', require far more skilled attention than the single species plantation, and the poor results have mainly been due to lack of this attention. Greater knowledge is required of the natural tendencies of the components of the mixture and of the consequences of the manipulations open to the silviculturist, and he must be constantly on the watch to control the silvicultural stream if he is to attain the best results. The probability is also that the form and nature of the mixture or final crop desired by the forester is decidedly different from what would develop if things were left to Nature.

[1] *Ind. For. Rec. Silviculture*, v. i.

DR. A. S. WATT.

In ecology, as in other branches of science, the dynamic approach has had a rich reward. Hitherto, emphasis has been placed on plant succession—the sequence of plant communities in time at a given place, the general climate remaining constant. In true developmental succession the change is attributed to the action of the plants themselves, whereby one community so alters the total environment that it becomes relatively more favourable to some components of the next until ultimately a complex is built up in which climate, soil, and vegetation are in equilibrium, and remain in equilibrium only so long as the vegetation proper to it is maintained. In the plant successions with which we are immediately concerned the vegetation develops to a stage where trees first come in (the pioneers), to be followed by a series, short or long, of other species of dominant trees (successor species) ending in the climax, any one of these in Sir Roy's terminology being called a successor species. Our immediate problem is the relation between pioneer and successor, but in ecological theory any dominant in the series may play pioneer to the next dominant. The basis of the problem is thus broadened to embrace the relation between any two successive dominants.

Although in this country the general trend in plant succession is from habitats of extreme wetness or extreme dryness to mean moisture conditions and from xerophytes and hydrophytes to mesophytes, the actual mechanism by which the entry and establishment of one dominant in the community of its predecessor are secured may not primarily be connected with the relation of the plant to moisture. Thus, in the succession on eroded sand in Breckland, *Cetraria aculeata* follows *Polytrichum piliferum*, because the latter provides a suitable physical anchorage; and in the hydrosere in fen, *Cladium mariscus* invades reed swamp when the accumulated organic matter causes the shallowing of the water to a point where adequate supplies of oxygen, entering the part of the leaf above water, are maintained to the growing parts of the plants below water. In both of these examples the entry and establishment of the successor species would seem to have a purely physical basis.

Considering next the order in which the dominants occur, we may take the succession on the South Downs as an example. There if the three species ash, oak, and beech start level, there will in time be a fractional separation into ash-woods, ash-oakwoods, and beechwoods. This separation is primarily an expression of a gradient in mobility aided by gradients in abundance of seed and earliness and frequency of its production, and conditioned by the gradient in light demand, and the sensitiveness of the seedling to frost. Here, beech can invade the woods of ash and oak receiving adequate light intensity in mature woods and protection from frost; in other words, it is adapted to the microclimate of these woods. The microclimate of scrub at certain stages of its development is equally suitable. Furthermore, cover, although desirable, is not always necessary, and beech can invade grassland directly. Thus, conditions suitable for beech establishment are found over the whole range of habitats represented by grassland, scrub, ash, and ash-oakwood. There is no need to postulate soil preparation or direct or indirect

root action. That does not mean to say these do not exist or there is not an influence which is favourable, but merely that the succession can be adequately accounted for in terms of the general biological equipment of the species without reference to any more specific relation between the successive dominants.

In the foregoing I have taken the South Downs as a whole with ash as the general pioneer tree, but there are places—the most exposed places facing south-west—where the relations between ash and beech are reversed. In these exposed places beech is the pioneer and ash the successor in so far as the establishment and growth of the beech provide conditions suitable for the entry and successful growth of the ash.

The number of wood-forming species in this country is so small that the species we have form woods over a wider range of habitat than they would had they to meet with competition from other species better adapted to parts of it: moreover, some form the climax simply because other life-forms proper to the habitat have been exterminated during the last ice-age or have not returned. The consequence is that our tree successions are short and provide only some of the data on which generalizations can be made about the contrast between the characteristics of pioneer trees and the climax species. Moreover, natural selection (including selection by the vegetation itself) has led to the survival of species with certain combinations of characters which fit the species for the part they play in succession. In general (and there are many exceptions in detail), pioneer trees of the xerosere are frost-hardy, light-demanding xerophytes, non-exacting as to soil, deep rooting or accommodating, insensitive to oxygen supply in the soil, and mobile. Successor trees and climax trees in particular are frost-sensitive, shade-bearing mesophytes, more exacting as to soil, shallow-rooting, sensitive to oxygen supply, and immobile. The outstanding fact about those species which act as successful pioneers in planting—the pines and birch—is that they have most of the attributes of pioneers: moreover, they grow in a wide range of climate conditions and play pioneer to different successors in different climates. This again would seem to exclude any specific relation between pioneer and successor.

Before considering Sir Roy's data in the light of these remarks, may I point out that the critical phases for succession in the life-history of a plant may be the germination of the seed and the establishment of the seedling. These are exactly the phases which are passed in the favourable conditions of the nursery. Nevertheless, a plant may retain some of its juvenile features for some years beyond the age of the transplant. Further, the plant which is put out in the field is not the same as a plant of the same size grown from seed on the spot; in particular the form of its root system is different, being fibrous, compact, and shallower. In fact the plant may be deprived of its main equipment for survival.

The evidence presented by Sir Roy seems to me fully to justify the practice of using a pioneer with a successor where a successor crop is desired. But how far this practice should be extended, and what conjunction of species should be used, should depend on an appreciation of how the pioneer acts. From what has been said already there is likely to be more than one cause at work, and the several causes may be operative to different degrees in different habitats.

In the investigation of cause I should put in the forefront an analysis of the microclimate. The data from Breckland about the response of Douglas fir five years after mixing with pine are capable of an interpretation in terms of a change in the microclimate; protection from frost and from drying winds only after the pines were of a size to provide it would seem to afford adequate explanation. The extension of the influence of the pioneer to pure crops of the successor both to windward and to leeward could be explained on the same basis, for, as Russian data on the effect of shelterbelts show, the wind velocity is less both to windward and leeward than it is over the open steppe. Also, the mingling of warmer air from a plantation with the colder air outside means that at ground-level during frosts there is a fall in temperature from the plantation outwards, and between plantations the blanket of cold air would be thickest in the middle and thin out towards the plantations on each side.

If there is anything in what I have said, then in areas where the microclimatic factor is important the amelioration of the local climate, however caused, would produce similar results. Thus a sufficient body of taller growing pioneer individuals in a plantation generally in check would act as a nucleus of amelioration, its influence extending beyond its limits and gradually spreading outwards. Again, the successful establishment of any woody species, whether shrub or tree, provided it had the same ameliorative influence as pine, ought to give similar results. From none of these, however, is root action excluded. On the other hand, the shelter provided by a stone wall should produce similar results, and the extension of the idea to the use of hurdles or canvas between the rows of trees is suggested for experiment with the observation that they would not afford the same kind and degree of protection as that afforded by spreading trees. In an anticyclone inversion protection would be negligible, but a light cover over the top together with side protection would provide the necessary experimental technique for finding out whether death or check in the successor was due to microclimatic causes. The primary need is to ascertain the cause of death or check.

In saying all this I am not arguing that the microclimatic factor affords a full explanation of the effect of the pioneer on the successor. I merely wish to point out that no convincing case has been made out for excluding it. On the contrary, in my judgement there is a prima-facie case for its fuller investigation.

Soils. In a virgin succession there is an increase in productivity with time, and in the climate of the region of brown earth soils the maximum productivity is reached near the climax. In podsol regions, however, the peak of productivity is probably attained at some distance short of the climax, and it is at least doubtful if the postulated relations between pioneer and successor hold. With virgin successions, however, we have little if anything to do, for the bulk, if not all, of the plantable land in this country has at some time or other carried woodland (not necessarily close-canopy woodland) and consequently belongs to deflected successions. The soils of these deflected successions differ in greater or lesser degree from the woodland soils from which they were derived and do not therefore necessarily present the same problems as in virgin successions. Some soils,

as those on the South Downs, retain sufficient of the major properties of woodland soils to be colonizable by trees whether pioneers or successors. Ash, although a pioneer in the deflected succession as already described, lacks some of the critical attributes of a pioneer and may not have been the pioneer in the virgin succession. In fact, I have for some years held the view, unsupported though it is by archaeological evidence, but backed by a considerable body of ecological data, that pine may have been a pioneer in the virgin succession on highly calcareous soils. Its usefulness in the establishment of beech was, therefore, not unexpected, and the need for a pioneer in plantations is quite compatible with the fact that beech may invade chalk grassland directly without the aid of a protective cover.

Besides these soils which retain the major properties of woodland soils, there are others which show all grades of change to extreme types so altered by erosion or waterlogging and peat formation that they no longer belong to the category of plantable soils. There are, however, in the intermediate grades large areas where the change has been less extreme with soils which retain the skeletal attributes of woodland soils such as depth, but whose texture and base status have been altered. These in the main are the direct or indirect result of human interference in the past, and the forester's task is not only to plant trees but to build again the old waste places so that they will in time be able to carry a crop of trees. Viewed thus, the forester's work calls for considerable patience and forbearance; his problems are also a challenge to man to restore to fertility the man-made wastes.

The building up of soils is in great part the work of plants, and for the continuation of the process there must be continuity in the plant succession, that is, a series of dominants with interlocking requirements must be present. If through any cause the necessary dominant is absent, the stage in succession reached will not necessarily stay at that level, but retrogression may set in. This may occur at different stages in the succession. Thus, in the absence of a sufficient binding force of grasses, the succession on eroded sand in the Breck reaches as far as a mixture of dominant *Cetraria-Cladonia* which on the decay of the anchoring *Polytrichum* disrupts, the soil is exposed, and through wind erosion the built-up soil blown away, exposing once again the erosion pavement from which the succession started. Again at a higher level in the hydrosere, as in lakes, plant remains may be accumulated to a point where *Phragmites* should come in. In its absence the existing plant community by further accumulation of organic matter makes the habitat worse for itself, and in time is no longer able to hold the ground; the accumulated soil is eroded and the succession starts at a lower level. Similar examples are found in peat, both in the raised bog and in blanket bog. At a still higher stage, and one of particular interest to us, destroyed woodland has been replaced over wide areas by *Calluna*, which through its highly dispersed acid humus accelerates podsolization. In extreme cases, as in parts of the Breck, this process has gone to a point where the soil and vegetation no longer form a stable system; the podsol is broken down and its component parts dispersed by wind to form the material for a fresh start. This is one of Nature's ways of restoring the position created by her insurgent son.

In slightly less extreme cases, as at Wareham, the retrogression has not gone so far, yet far enough to make even the establishment of a pioneer difficult. In most areas the establishment of a pioneer is possible, and by its aid a successor may achieve success. The problem at issue is how.

The effect of trees on the soil of such *Calluna* areas has not, so far as I am aware, been the subject of inquiry, and on the general problem of the changes in soil wrought by scrub and by forest there is little exact information from areas in this country. The unpublished work of Ross on the effect of scrub on the heavy chalky boulder clay west of Cambridge confirms the general opinion that the texture of the soil is altered. Whether this alone is sufficient to account for the success of the successor or whether other and more subtle changes are brought about needs further investigation. This, however, can be said: that anything, be it texture or aeration, which favours the absorption of transpiration balance in the transplant will help the trees. To that extent at least the condition of the soil is important, and woodland soil is generally in a better physical condition than soil under *Calluna*, when the pine and birch, which are less sensitive to oxygen, have a greater chance of successful establishment than the more sensitive climax species. On this point one would like to see or hear of experiments on the effect of the pioneer on the successor on contiguous areas with woodland and non-woodland soils respectively where it can be demonstrated that the micro-climatic factor and the vegetational or biotic factor are the same.

The Relation of One Plant to Another. The subject of the relation of one plant to another raises issues too vast to be discussed in detail. Broadly, the relations may be classed as dependent, competitive, or mutually beneficial. The relation between plants is not always in one category; a tree may provide shade and shelter to its dependant and yet compete with it through its roots; the relation between legumes and grasses is both mutually beneficial and competitive; the relation between a fungus and its host in mycorrhiza may be all three. It seems to me, therefore, to prejudge the issue of the relation between pine, say, and spruce by writing it down as always competitive. Such relations are usually dependent on the conditions, and I see nothing inconsistent in the view that young pine on *Calluna* ground may be beneficial to young spruce, while on other soils and at other ages the relation may be competitive. Grass on the floor of a wood depresses the growth of ash; beech, so far as I know, is not similarly affected; in a mixture, beech by killing out the grass will *in that way* favour the ash. Similarly, pine is a normal invader of *Calluna* heath; by killing the *Calluna* even partially root competition between spruce and *Calluna* would be reduced. Nor can we exclude even more subtle relations; the annual shedding of mycorrhiza by pine may provide suitable nutriment to spruce, and even the dead roots of *Calluna* may do this. And the further possibility exists of direct action through root excretion. The significant association in the Californian Desert between certain species of annuals and certain species of shrubs alive, dead, or decayed provides an example of an intimacy which suggests some chemical action. Our ignorance of such matters is, however, fairly complete.

The problem of mixtures as distinct from problems of establishment raises

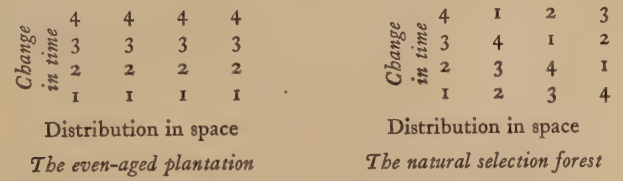
other issues. The claim that a mixture of deep-rooting and shallow-rooting trees has a higher yield may be valid. Dredge corn (a mixture of oats and barley) is claimed by its growers to produce a higher yield than either of its components. The claim, however, has never been substantiated by experiment and the issues involved are complex; the relation between the components may be complementary nutritional, the direct action of one kind of root on another may be microbiological. Similarly, the vertical stratification of the roots and shoots of species in the different layers of a wood may reduce competition but does not exclude it. This raises the whole question of the structure of a plant community.

The Structure of the Plant Community. I began by pointing out that the dynamic concept had been successfully applied in the interpretation of vegetation as a whole. I should like now to consider its extension to the plant community itself, and to show, first, that the phenomena of the plant community are essentially of the same kind as the phenomena of plant succession, that is, the relations between components of the plant community are dynamic and based on the reactions of the plants themselves; and second, that many of the forester's difficulties result from the non-natural, man-made structure of much of our vegetation.

On the better soils of the Chiltern plateau, birch plays pioneer to the successor beech (the intermediate stages may be omitted for simple treatment). On such soils the struggle between them is a foregone conclusion; the light-demanding and small birch is no match for the tall shade-bearing beech. Inside the beech-wood the beech regenerates without the aid of birch. On the other hand, on the poorest soils beech loses its advantage of height and, failing to reproduce under its own canopy, gaps are formed in which birch plays the part of pioneer. Under the birch the surface soil is changed from a mor condition to something near a mull; beech comes in and growing under the birch finally prevents birch from reproducing in that place. The same cycle is repeated in other gaps, and the wood taken as a whole is a stable birch-beech wood, in which at any given time the proportion of birch to beech may vary, but birch will always be a constituent, and one perhaps necessary to the continued existence of the beech. Thus, the scales which, on the better soils, are heavily weighted in favour of the beech so that succession takes place are on the poor soils more evenly balanced, the progressive component of change leading to succession being effectively offset by the inability of the beech to maintain continuity in space and in time over the whole area. The two phenomena, namely plant succession and the internal cycle of change, are the same in principle. And although it may be convenient to treat them separately, the establishment of woods by mixing pioneers and successors and the maintenance of mixtures in plantations rest on the same kind of natural process.

Next compare the pattern of an even-aged pure plantation (i.e. a crop) with a natural forest or with its nearest equivalent under management, the natural selection forest. In the life-history of an even-aged pure plantation there is a definite sequence of change in time. As the trees grow the number per unit area falls, their power to exclude invading species also falls, and subsidiary vegetation

makes its appearance, marking stages in the life-history of the plantation. Thus in certain Scottish pinewoods the absence of ground vegetation following the formation of canopy is followed by the succession of dominants, *Deschampsia flexuosa*, *Vaccinium myrtillus*, and *Calluna vulgaris*. Denoting these stages by the numbers 1 to 4, we have the scheme on the left showing the distribution of the stages in space and the change in time. Compare this with a pinewood managed on the selection system (scheme on the right).



At any given time there is a patchwork of ground vegetation representative of all phases in the life-history and related to the competitive power of the trees. Also at any given place in time there is the sequence of change found in the even-aged plantation. The selection forest illustrates the dynamic pattern or cycle of change, the minimum time required for its completion being the length of the rotation.

Now consider the relation of these systems to an invading species of tree. Unless the species comes in at the beginning, that is with the dominant, its successful establishment in the even-aged wood will have to wait until such time as the competitive power of the dominant is reduced with opening up of the wood; let us say until stage 4. In the selection forest, on the other hand, the invader can immediately become established in those places at No. 4 stage; and since in time every part of the wood will pass through that stage, the invading species will have an opportunity of invading each part of the wood. Whether the invasion will lead to succession or to a stable mixed wood will depend on the relative competitive power of the species under the given set of conditions.

Because it is regularly burned the *Callunetum* as commonly seen in this country has the structure of a crop or an even-aged pure plantation. An invading species may come in at the beginning after burning, but in the 'tight' heather stage difficulties are presented just as in the middle stages of the plantation, and it is only when the heather becomes old and leggy that a further opportunity is given. This does not usually happen because of burning before that stage is reached. Unburned heather, however, shows a structure comparable with that of a selection forest; it is uneven-aged and shows a dynamic pattern with old leggy or stick heather appearing at intervals. These are the invasion points for pine, that is, places where the old and dying heather no longer presents the same level of competitive power. Again, just as in the selection forest, the whole area is capable of being invaded by pine and the minimum time required is the length of life of heather in this country, namely about 25 years.

Much of the so-called natural vegetation of the country has this crop structure. Scrub may be so dense on the ground that its invasion by trees is impossible until with age it opens out, the uniform crop-like structure arising from a sudden

release from grazing or from arable cultivation. The 'tight' stage in yew-woods may last several hundred years before the wood opens out to allow the entry of invading species. The bulk of our broadleaved woods have this crop structure consisting of grandparents without issue. Grassland previously grazed and then enclosed against rabbits shows a uniformity and competitive power arising from its crop structure which increases the difficulties of establishing trees. To give the devil his due, the rabbit is not one hundred per cent. hostile. Left to themselves all these types of vegetation would in time show a natural as opposed to a crop or artificial structure. This is not to be interpreted as an argument for delay in planting; I am merely trying to outline the framework within which explanations of the forester's difficulties may be looked for.

The problem of mixtures has engaged the attention of foresters for a long time, and in their understanding of the relations of one species of tree to another forestry practice is ahead of ecological theory. By determining the kind of dispersion which species show in a plant community, Dr. Clapham and Dr. Blackman have made a first attack by statistical methods on the problems presented by its structure. The next step is to find out how species are related to each other. This has been done for a number of plant communities whose structure is relatively simple, and the data show that the same fundamental relations as seen in the natural selection forest, whether it consists of one species of tree or more, hold for the non-woodland community as well. In other words, there is on the ground at any given time a pattern, like the pattern of a carpet or a wall-paper, but unlike these the pattern is dynamic, the components moving from place to place in time but always showing the same basic relation to each other. The recognition of this pattern, and the study of the relations of the species composing it, are of primary importance, and to my mind constitute the most urgent single problem in what may be called straight ecology. It even raises the fundamental issue of what constitutes a plant community. In his essay on the poems of Robert Montgomery, Macaulay makes some remarks apposite to this issue.

'His writing bears the same relation to poetry which a Turkey carpet bears to a picture. There are colours in the Turkey carpet out of which a picture might be made. There are words in Mr. Montgomery's writing which, when disposed in certain orders and combinations, have made, and will again make, good poetry. But, as they now stand, they seem to be put together on principle in such a manner as to give no image of anything "in the heavens above, or in the earth beneath, or in the waters under the earth".'

In other words, you may bring together the elements of forest from divers sources and yet not make a forest. A good forest must be racy of the total environment, including the relations between its members.

Further, it is not merely a question of the association or grouping of species selected by the organic and inorganic environment, but of the way in which the species and individuals of the species are put together to form a pattern in space and in time—'their disposition in certain orders and combinations'. There are really two components to this problem, the proportion of one species to another and the way in which the species are associated. For example, fescue-bent

pastures show all transitions from pasture with abundant fescue and negligible bent to abundant bent and negligible fescue, that is, the proportions of the species vary. As yet we do not know what factors determine the numerical relations of these species. But there is the further question to which there is also as yet no answer, of the pattern which they make or the way in which they are put together. Put in its simplest form, the problem in a mixed plantation may be represented by a comparison between the stem-for-stem mixture and the line-for-line mixture. In the diagram

Stem-for-stem mixture	*Line-for-line mixture*
a b a . . .	*a b a . . .*
b a b . . .	*a b a . . .*
a b a . . .	*a b a . . .*
. . .	. . .
. . .	. . .
. . .	. . .

the proportions of the two species are the same, but the record of density takes no account of the relative position of the species, for in the stem-for-stem mixture *a*'s nearest neighbours are 4 *b*s and in the line-for-line mixture $2a+2b$. Thus the two systems are not the same. And this raises the further question of the size of the unit in the dynamic pattern; in some habitats a mixture of two species may succeed as a stem-for-stem mixture, in other habitats for the best results the same two species ought to be planted in groups and in groups of different sizes according to the habitat.

These ideas are more familiar to foresters than to ecologists. Ecologists in fact have a long way to go before they know enough about the relations between species in the plant community to make generalizations which will be useful in the practice of forestry, and to achieve this desirable goal much more intensive study of the static and dynamic structure of the plant community is needed. The same holds good in the diagnosis and delimitation of plant communities; the forester can diagnose *Callunetum* as easily as the ecologist; but there are *heaths* and *heaths*, and to be of real service the ecologist must in his systematic work on plant communities be a 'splitter' and not a 'lumper'. Here again pattern as a criterion will be of service.

Professor Tansley's *Vegetation of the British Isles* is a landmark. It is the climax of a phase in which the main theme has been the relation of one plant community to another. The next stage, in my view, will be the intensive study and elucidation of the dynamic relations which hold between one species and another in the plant community itself. The establishment of generalizations based on information of this kind and the focusing of these on the special problems of the forest should be to the mutual advantage of the forester and the ecologist.

PROFESSOR H. M. STEVEN.

It may be useful to mention what ecological studies are of special value and interest to foresters. Apart from vegetation, both ecologists and foresters are

particularly concerned with factors of locality. As ecology passes from the descriptive to the experimental phase this common ground will extend.

Experience of afforestation in this country has shown the importance of a close study of climatic factors both general and microclimatic.

Although the study of ground vegetation types has proved of great assistance in afforestation, soil profiles when properly understood may be expected to give even greater assistance, because therein was reflected the past history of the site and the reaction of its vegetation over a long period. Each soil type had characteristics of value in deciding silvicultural technique. Of paramount importance, however, was the nature of the leaf litter and humus. In the formation of plantations the nature of the leaf detritus of the ground herbage plants, and the species from which it was derived, affected tree species in different ways, and was at least one cause of the behaviour of pioneer and successor species. It, therefore, affected choice of tree species and mixtures. Later it influenced thinning technique, and was of critical importance in systems of natural vegetation. Indeed the whole of silviculture may be viewed from this point of view.

Secondly, the ecological concept of climax was of importance in afforestation in this country. If certain upland heaths and peat lands were edaphic climaxes as envisaged at one time by Professor Tansley, then their successful afforestation would meet even greater difficulties than had been encountered to date.

Coming to the concept of succession, it would undoubtedly be of great value in silviculture if ecologists could work out in greater detail the mechanism of the reaction of seral stages in improving the habitat. This knowledge would have wide application. Mixtures of hardy tolerant pioneers with successor species may not prove successful on the most difficult sites, e.g. probable edaphic non-woodland climaxes. It may be necessary to have pure crops of the pioneers as well as special soil cultivation technique, introducing the more valuable successor species at a later stage.

Finally, the reaction of a community on the soil type is of vital importance from the point of view of the maintenance of soil fertility. In this connexion, has the preponderance of light-demanding species in the natural woodland communities of this country any ecological significance?

DR. L. DUDLEY STAMP.

I am particularly interested in the discussion as it affected the broader issues of national land-planning. Reference had been made to the very varied physical environments of our relatively small country, and there was need of detailed study that full use might be made of all types of land in the national interest. Expressed in simple terms, the land must satisfy five of the major needs of the people—land for industry, for housing, for food, for raw materials (including timber), and last but not least for recreation in the broadest sense—refreshment for mind and body. Since it was true that our climate is essentially a forest climate and that woodland was the climatic climax vegetation of most of the surface, there was danger of a competition between afforestation and other uses. Unfortunately it was true that the competition between industry, housing, and agriculture was

fiercest for the *best* land—level or undulating, well-drained land equally suitable for 'development' as for farming and, it must be admitted, for forestry. The danger disappeared, if forestry were made the solution for the use of the poorer land of the country and if Professor Tansley's concept were accepted that afforestation was primarily a matter for what geographers call 'Highland Britain' —the old-rock massifs of the west and north. Public opinion was conservative and needed to be educated to the realization that this country could, if it liked, possess something of the stately charm of the Black Forest, the fairy quality of the Finnish forests sprinkled with birch and aspen, or even the incomparable majesty of the Californian Redwood Highway. The vision seemed particularly attractive for the Scottish Highlands, where at present virtually uninhabited deer forests covered nearly a fifth of the whole country and where it could not be said that the hill sheep had a prior claim, since only 3 per cent. of Scottish hill sheep grazed in the deer forests.

Was it possible that the ecologist held the essential key to the problem of the best use of land, especially hill land? Broadly speaking, rough grazing—land agriculturally sub-marginal—covers some 18,000,000 acres or a third of England, Wales, and Scotland; the areas which it covers are shown on the new maps of land utilization (recently printed by the Ordnance Survey in two sheets on the scale of 1 : 675,000 for the Land Utilization Survey of Britain and the Ministry of Town and Country Planning) which were exhibited, and the character of the rough grazing was shown for England and Wales in Stapledon's *Grassland Survey* of which a coloured manuscript copy on the same scale was exhibited. Armed with such maps and his knowledge of the succession, could the ecologist delineate those areas where grassland improvement was the best course in the national interest and others where afforestation should be paramount? There did seem to be a possibility that tracts would remain—for example of *Eriophoretum*—which nobody would want, though such might be the essentially remote tracts needed for nature reserves. Referring to a possible competition between hill-sheep farming (so essential for the maintenance of our live-stock industry) and forestry, there seemed to be the problem of the unplantable land: whilst the productive value of *part* of a tract of hill land was being raised by planting, that of the remainder was being lowered since it was neither plantable nor, as left, useful for sheep.

I hope that ecologists will play a major part, in the first instance through a nation-wide survey, in the determination of a balanced use of the nation's land resources. There was need for the practice of the old-fashioned virtue of thrift; there was nothing incompatible between proper use of land and what is usually called its 'amenity' value, and only by properly planned use should we secure the conservation of adequate tracts where the indigenous flora and fauna could still exist.

MR. J. MCDONALD.

There is a danger that the problems facing the forester may be oversimplified. The concept of the silvicultural stream must take account of the fact that such

streams vary in speed and even in direction of flow. On the chalky Boulder Clay of Lincolnshire, for instance, the movement towards forest is very much faster than it is on the Bunter Sands of Sherwood Forest. In relation to broadleaved woodland, while the climax types of tree in this country may constitute forest to the ecologist, to the forester they are woods not worth their keep—as, for instance, oak on dry acidic soils. Can the ecologist tell, then, how forestry can be made productive without planting conifers?

With regard to the scarcity of shade-bearers in the country, referred to by Professor Steven, some of this at least may be due to the influence of the game preserver, either in cutting out, or in refraining from planting, heavy shades, with a view to the conservation of ground cover.

Professor Tansley had referred to study of the autecology of exotic conifers. While agreeing that more extensive knowledge is needed here, it may be suggested also that we require information about such native trees as will mix readily in plantations; e.g. lime is well worth keeping, and, at least in the midlands, it mixes well. Foresters, however, know very little about our native trees. They do know that wych-elm and sycamore grow well. But where should they be put?

The reconstruction of our broadleaved woodlands has been sadly neglected. Professor Champion has recommended protection. This may help, but only on the better soils. A recasting of the future training of foresters and forest officers, with an increased weight of emphasis on ecology, will also lead to a solution of this and many other problems.

MR. W. H. GUILLEBAUD.

I agree with Professor Tansley's statement as to the need for studies on the autecology of the more recently introduced exotic species of forest trees, referring to the numerous experimental areas laid down by the Research Branch of the Forestry Commission. These areas contained comparable plots of many of the exotic species. The Research Officers would welcome any opportunity of showing these experiments to ecologists who might be interested in this problem.

A little further light has been thrown on the nature of the changes produced by the growth of the pine in the pine/spruce mixtures referred to in Sir Roy Robinson's paper. Observations at Teindland, by Dr. A. Muir of the Macaulay Institute of Soil Research, show that one effect of the pine is to produce a thin but well-defined layer of black raw humus on the surface of the soil, and that in this layer the finer spruce rootlets are strongly developed. Where there is no pine with the spruce the peat is undecomposed and of a greasy texture and there is no superficial layer of raw humus. In another experimental area in Scotland plots of pure spruce adjoin plots of Scots pine and of Japanese larch, and the two or three rows of spruce next the pine or larch show greatly improved growth compared with the spruce in the rest of the plot. Dissection of the roots of some of the spruce shows that the roots of the trees in the penultimate row are markedly longer and stouter in the direction of the larch or pine than they are in any other direction. Both the above observations show that whatever benefit the pine may

confer in the form of shelter, there is also an edaphic effect of considerable importance.

Graphs illustrating the development of the spruce in pure and in mixed plots at Teindland and Allerston experimental areas were demonstrated to the meeting.

DR. G. E. BLACKMAN.

It has been stated at this meeting that the agricultural approach, at least so far as soils are concerned, is a hindrance rather than a help in the consideration of forestry problems. It is, therefore, with some hesitancy that I venture to make suggestions as to the interrelationship between afforestation and ecology because I admit in part to an agricultural outlook.

As an ecologist with experience of agricultural research, I am firmly convinced of the value and importance of statistics and statistical methods in the solution of agricultural problems. I am equally convinced of the importance of the same methods for autecological investigation, especially in woodland communities. This conviction is based not only on general grounds but also on the knowledge acquired over several years during investigations on the autecology of a woodland plant: a plant admittedly of no economic importance but with a high amenity value—the bluebell. By the application of statistical methods in field studies it was possible to establish that where the mean light-intensity over the period March to June did not exceed 10 per cent. of daylight no bluebells existed. Furthermore, by conducting parallel experiments in the open, where plants were subject to varying degrees of artificial shading, it was found that no gain in weight took place below an intensity of one-tenth daylight. Thus the two sets of figures obtained by experimentation and by direct observation in the field are in good agreement.

I do not quote these figures for their intrinsic interest to foresters but only to show that by controlled experiments coupled with field studies it has been possible to define precisely at what point light as one of the environmental factors of woodland will limit the establishment of the bluebell. There is, moreover, a further point. As far as I am aware, accurate data of this nature are not known for any other woodland plant. Yet such information for tree seedlings must be of primary importance in problems connected with natural regeneration and the degree of selective felling required to give optimal light intensities for the establishment of seedlings.

I do not wish to imply that investigations should be confined to the minimum light requirements of trees and other woodland plants because with increasing light-intensity other factors may become operative. There is, for example, evidence that under some American conditions the fall in moisture content associated with rising light-intensity will determine the limits within which regeneration will take place. It cannot, however, be taken for granted that woodland species will necessarily grow best under the conditions of the woodland environment. In point of fact the bluebell has the highest growth-rate in the open and is rarely found outside woodland in south and eastern England, because of the competition for water with grasses and the damage caused by grazing

animals. In the higher rainfall areas of the north and west, bluebells will grow in full daylight in localities where grazing is infrequent in the spring and the soil is not waterlogged. There are a number of other contributory factors which, though they may play some part in determining the distribution, are of minor importance and need not be discussed.

This information I have given for the bluebell will, I think, serve as an illustration of how it is possible to analyse with some precision the complex of environmental factors by combining detailed field studies with multifactorial experiments. The main point I here wish to make is that investigations along similar lines for both indigenous and exotic trees should go far to elucidate many forestry problems and make it possible to predict where tree growth would be satisfactory. Reverting again, if I may, to the bluebell as an illustration, it can be stated that the replanting of clear-felled deciduous woodland with evergreen conifers will lead to the elimination of the bluebell, but that by mixed planting of deciduous and evergreen trees in proportions that can be calculated this elimination will not take place.

Sir Roy Robinson, in his discussion of the problems of accelerated succession, has stressed the importance of detailed observations in plantations set aside for ecological investigation. Of the value of such observations there is no doubt, but it seems to me that a full understanding of the successional changes taking place cannot be achieved by these means alone. In addition to these plantations new experimental plantings laid out in randomized blocks are required. The design of such experiments, since they must be essentially long-term, will need careful thought and discussion between foresters and ecologists as to which factors are likely to be of most importance. One factor which must be investigated is the effect of varying the distance between the rows of the pioneer species on the growth and development of the intervening exotics.

Coupled with these large-scale trials other smaller experiments are required where the environmental factors can be changed experimentally. Such investigations must embrace direct measurements of growth and probably physiological changes, since if the function of the pioneer species in mixed plantations is associated either with shelter or shade, then the effects may be extremely complex. From work now in progress at Imperial College it has been found that in annual plants a reduction of light-intensity to half daylight increases the height, leaf area, and the proportion of stem dry-matter, decreases the root weight, net assimilation rate, but does not change the total plant weight. Moreover, the extent to which these alterations will occur can be widely affected by variations in the mineral nutrient level, and at different times in the season some trends may even be reversed. Whether tree seedlings will react in the same way as annual plants is unknown, but the sudden onset of extension growth of exotic conifers described in Sir Roy Robinson's article may be brought about only after some degree of shade has been established by pioneer *Pinus silvestris*.

It may be thought that the programme of research as outlined is in scope and detail formidable, but so, too, are the problems concerned with the post-war afforestation. If these problems are to be in part solved in time to be of practical

value during the next decade, then the situation calls for co-ordination and intensive investigation by teams of workers. Primarily an ecological survey of Great Britain as suggested by Dr. Stamp will be of great help, but as Professor Tansley has pointed out, ecology is a young science and I personally doubt whether the present state of existing knowledge is sufficient to foretell within narrow enough limits which localities or communities are suitable for tree planting. Ecologists would welcome the opportunity of extending their knowledge in this direction, but in the past they have been hampered by lack of numbers, facilities, field laboratories, and finance. If these obstacles were removed, then the advance of knowledge should be rapid enough to help solve the difficulties of the post-war programme of afforestation.

DR. M. C. RAYNER.

There is one aspect of forest ecology that I take this opportunity to stress. Except in relation to root diseases, I think that plant ecologists have tended to overlook—certainly to underrate—the importance of soil fungi in general as potential factors in the ecology of the Higher Plants. This is especially true of trees and particularly of certain groups.

My own views have recently tended to crystallize. I regard the mycorrhizal habit in trees as a specialized ecological relationship, the distribution and activity of the mycorrhiza-formers being closely bound up with the whole complex of biological soil activity in relation with the kind of humus substrate that is being formed. Under natural conditions, the establishment of balanced mycorrhizal relations is in itself a formal condition for healthy growth.

The members of certain groups of trees—Abietineae, Cupuliferae, and others—show a multiple habit in respect to mycorrhizal association, and I think it likely that the capacity to form regular and stable root associations with a number of different species of soil fungi is in itself an ecological adaptation bound up directly with other edaphic factors.

In the establishment of a new ecological unit during afforestation, sometimes all goes well and the complicated biological soil factors become automatically adjusted to form a stabilized system. Often there are difficulties, and we have learned that disturbance of edaphic relations is apt to be quickly reflected in mycorrhizal equipment, so that the incidence and structural features of mycorrhizas are a valuable index to the suitability or otherwise of soil conditions, and may be a useful guide to their modification.

In the case of trees, convincing evidence is now available as to the delicacy of these ecological adjustments and the sensitiveness of tree growth to their impact. For example, the disturbance of ecological balance that occurs after felling is quickly followed by an obvious shift in the fungus population. This, together with the change in the character of the organic detritus that reaches the soil, will bring about alteration in the humus substrate, which may in turn react on the behaviour of new plantings if made during a period of ecological instability. Also, when attempting experimentally to introduce suitable mycorrhiza-formers in a soil inoculum from a native stand of the species concerned, there is a danger

of bringing in also undesirable soil fungi—relatively innocuous under native conditions, but very deleterious to growth when introduced into a new soil environment. There is good reason, also, to suspect that the poor growth shown by some so-called geographical races of, say, Scots pine or Sitka spruce, may be directly associated with—among other factors—maladjustment in respect to the species or strains of mycorrhizal fungi available.

In general, it may be safely concluded that the mycorrhizal relations of trees in natural soils are with native fungi growing freely in these soils, and that these must therefore be included as ecological factors of great or even critical importance in any ecological concept of the habitat.

DR. A. FOGGIE.

I should like to make a few very brief remarks on some instances bearing on this problem which I have noticed in Cyprus and West Africa. These remarks are merely observations; there are little or no detailed records or research to back them, for if we know little enough of fundamental causes in this country, in the colonies we know considerably less.

First in Cyprus. In the hill forest area in which I spent most of my time the principal timber species was the pine *P. halepensis*, which must undoubtedly be classed as a pioneer species, exceedingly drought resistant, and when established capable of growing successfully on the bare, deeply fissured andesitic rocks which constituted the soil, so-called, over large parts of the area. When mature and its bark had not been destroyed by blazing for resin tapping, it was also resistant to fire and there was evidence that it had replaced the cedar, *Cedrus brevifolia*, over large areas of the Paphos Forest, the cedar only occurring in four small isolated relics to which it had been reduced by fire and goat grazing to the advantage of the pine. There was also evidence that the Aleppo pine had occupied areas formerly stocked by the Troodos pine, *P. nigra* var. *Pallasiana* or *Caramannica*, after the heavy fellings of 1914–19 in Troodos Forest. Some of the best areas of young crops were also to be seen on abandoned vineyards from the rapid colonization of bare cultivated soil. In these cases there was a soil of about 18 inches depth, a red-brown light sandy loam.

In the forest area which I knew best there was little artificial regeneration or afforestation as the major part of the crop was being worked under a group selection system, but owing to fires we had a certain amount to do. This was attempted by sowing or planting one-year seedlings of Aleppo pine on lines along the contours. I say attempted, as the success in early years was negligible. In this country a forester is troubled if he only attains an 80 per cent. or so successful establishment 3 or 4 years after planting. In Cyprus, if we had about 20 per cent. survival after the first summer and 10 per cent. after the second we thought there might be some chance of success and the method was worth continuing. Only sowing, or planting 1-year seedlings, gave these partial successes. Using larger plants, 2-year seedlings, 1-year transplants, or more, you were almost certain of a 99·9 per cent. failure except in gully bottoms or by springs, as the root systems were quite unadapted to secure the necessary moisture in the planting

area. And this was using an indigenous hardy pioneer species, seed being of strictly local origin, and of which there might be flourishing crops all round the burned area whose reafforestation was being attempted.

The Aleppo pine was mycorrhizal in rooting, flourishing seedlings in the nursery having fine mycorrhizal club rootlets; and influenced by reading of Dr. Rayner's early work at Wareham, I thought the mycorrhizal fungi might have been destroyed in the surface soil by the fire. Experiments proved this was not the major cause if it occurred at all, and it was left to Mr. Chapman, my successor in the division, to show that the major causes of death were heat lesions and sun scorch, the surface temperature of the soil either reaching the critical temperature of over 120° F. and causing heat lesions, or the air round the aerial shoot, owing to radiation from rock faces or lack of local circulation, reaching the same temperature.

The pine, though undoubtedly a pioneer timber tree species, is not under these conditions a member of the primary sere. Untouched, a burned area in the Cyprus pine forests is colonized after the winter rains by a flush of annual or short-lived grasses and a flush of new shoots from the roots of the *Cistus* and other sub-shrubs forming the regular forest floor, and it is only after these have grown up to give partial shelter to the pine seedlings that successful regeneration by the pine occurs. It must be remembered that the Mediterranean vegetation except in definitely wet spots is not a closed vegetation; there is always bare ground between the individual plants where new-comers can start and survive if they can compete with the occupants for water, and here the seedling of the pine which will send a tap root of over 6 feet in length down after moisture in its first growing season is well equipped to compete with the shrubs. A *Cistus* cover is not at all like dense heather cover.

That this was what did occur in nature could be seen in a burned area dating from 1924 in which attempts at artificial restocking about 1928 had entirely failed and had been abandoned as the area could not be adequately protected from goat grazing, but when I last saw it in 1936 large areas where the *Cistus* was fairly luxuriant were filling up with pine regeneration browsed to the level of the *Cistus* by the goats.

In many cases, however, we could not leave areas to recover slowly by this method; the erosion was too great. The average slope in Paphos was 30°. In such cases we had artificially to stabilize the soil by brush and stone terraces, cut contour trenches, sow them up with pine, and artificially create the conditions necessary to success by setting up brushwood shades above them. Laying brushwood over the soil merely created conditions for sun scorch by preventing air circulation round the seedlings.

Therefore the forester must not confine himself merely to the succession of the woody species he is interested in, he must know the dynamic ecology of the whole biome (cf. hawthorn and beech on Buriton).

West Africa provides entirely different conditions. There the problem is not to get things to grow but to prevent too many growing. The species which present conditions of demand render commercially valuable, and which the forester therefore wishes to grow in greater quantity, are a mere dozen or so out

of about 200 species occurring in the upper canopy of the natural forest with 1,000 or more woody species.

Those I worked with were the mahoganies, *Khaya ivorensis*, *Entandrophragma* spp., as species of primary importance, and *Triplochiton scleroxylon*, *Terminalia ivorensis*, and *Guarea* spp. as species of secondary importance. Of these species, those of primary importance occur but sparingly in what is considered the climax forest. *Khaya* and *Entandrophragma*, though present in all types, only occur as characteristic dominants in an area where rainfall and soil give a slightly less moist environment described by Chipp as a preclimax. *Chlorophora excelsa* occurs in the climax association and in all preclimaxes, but, from its size-class distribution there, does not appear to be maintaining itself in any of them. It appears to require conditions of a sere or subsere to establish itself when its apparent longevity allows it to hang on into the climax or preclimax stage. I say apparent longevity as all ecological work in the tropics is greatly hindered, as few of the trees have visible growth rings, and for those that have it has not been determined what relationship they bear to the seasons or chronological year.

The artificial regeneration practised in the Gold Coast is all by *taungya* methods, the forest being felled and burned, then the soil between the stumps cultivated by the native farmers by hoeing, and a new tree crop and their agricultural crops, corn and plantains, being put in simultaneously. Stumped plants are used. The area is farmed 3 years; then the regrowth of coppice and seral weeds, herbaceous climbers, shrubs, e.g. *Alchornea*, and the short-lived weed trees *Musanga Smithii* and *Trema* sp. is so great that the return to be expected from further cultivation is not worth the work and the farm is abandoned. Present forestry practice is, however, to continue cleaning along the lines of planted trees, which are fairly widely spaced, and do not and will not form a canopy for a considerable time, as the *Khaya*, *Entandrophragma*, and *Chlorophora* do not form a wide crown in early youth but simply send one strong leader upwards. In this we do not know whether we are following Sir Roy Robinson's silvicultural stream or not. From nursery work and early planting experience we know that the *Khaya* and *Entandrophragma* like a lot of light and *Chlorophora* a fair amount of light for rapid growth. *Khaya* planted in narrow lines in the original forest without disturbance of the upper canopy simply stood still or died. Yet in untouched forest occasional seedlings can be seen, and often a fair proportion of small trees reaching the upper canopy occur as well as the big mature dominants, especially in the *Khaya-Entandrophragma* preclimax. Work of this nature with indigenous species is very much in its infancy in the Gold Coast and we do not yet know what success will attend these plantations in later life, but it might be preferable to let the weed-tree species, *Musanga* and *Trema*, form a canopy and let the *Khaya* and *Entandrophragma* push their way through, when these short-lived species collapse. They would then, however, have to compete with *Ricinodendron africanus* and many other rather longer lived trees which also appear in abundance. Among them are *Triplochiton scleroxylon* and the *Terminalias*, principally *T. ivorensis* in the Gold Coast, which are species having a commercial value at present.

In Nigeria a method is being tried, which was just being started in the Gold

Coast when I left, of planting alternate lines with *Triplochiton* and *Terminalia* as these species develop comparatively broad crowns in youth, to see if they would form canopy between the mahogany rows and suppress the *Musanga*, *Trema*, and other weed species, then grow up with the mahoganies, thus cutting out ('telescoping') one stage in the probable succession.

Until a proper knowledge is obtained of successional phases within the natural forest and in man-made seres, however, our silvicultural practices will be purely empirical of the hit-and-miss variety.

PROFESSOR T. G. B. OSBORN.

Professor Osborn accorded warmest welcome to the offers of co-operation between forester and ecologist made by Sir Roy Robinson. This was a very productive field, and he hoped that both ecologist and forester would derive great benefit from future collaboration. There had been expressed certain criticisms of the concept of the silvicultural stream, for the most part on the grounds that it oversimplifies what is in fact a very complex phenomenon. Sir Roy was, however, familiar with many streams, and he undoubtedly, in putting forward his hypothesis, had in mind the 'braided' stream, with its many channels and currents. He wished to emphasize Professor Champion's reference to the great diversity of forest conditions in our small islands. Differences of rainfall alone would account for much of this, not to mention variations in soil, aspect, geological strata, and the like. He would also support Professor Steven in his references to the necessity of determining whether or no a community represents an edaphic climax before planning an afforestation programme.

DR. E. W. JONES.

Dr. Jones vied with Dr. Blackman in expression of the humbleness of the ecologist before the inquiring forester. Ecological work may be of two main kinds: (*a*) that devoted to the elaboration and study of ecological theories and concepts, and (*b*) the close study of environmental conditions and their effects on the individual, including here, autecological work. On the basis of theory and concept the forester often asks what is the course of succession and the nature of the climax. The ecologist's evidence is, however, very tenuous. There is very little concrete evidence as to the nature of the climax in the North Temperate Zone, and our views on it are highly theoretical. In North America 90 per cent. of this climax was destroyed before it could be examined, and this particularly in the east, where it most resembles the European. The idea also of selective regeneration may be called into question. The course of events is too often cataclysmic. A stand matures, and then falls to pieces and is replaced by another which may not necessarily be of the same species.

But in autecology we are on safer ground, and can be of much greater immediate use, provided that the ecologist becomes more familiar with the problems confronting the applied scientist, be he forester or agriculturalist. The practical man, however, already knows much of what the ecologist is still groping after.

DR. A. R. CLAPHAM.

Dr. Clapham referred to the opposition of interests already mentioned by Dr. Stamp, between agriculturalist and forester, in that both are after the same land, the one for grassland improvement on hill grazings, the other for afforestation. He asked also for the preservation of at least some fragments of our old broadleaved woodlands for ecological study, pointing out that it was from the examination of these that much information could be derived which would aid the forester in planning his future programmes.

Referring to the *Biological Flora*, now in course of preparation by the Society, he indicated the importance of the autecological studies which it comprised. He suggested that this flora was not confined to our native species, and it would be invaluable if members of the guest societies would offer memoirs on exotic trees, such as the larch, Norway spruce, and the like.

MR. W. R. DAY.

Exposition and Research. There is need not only for ecological research into problems concerned with forestry, but also for the exposition and demonstration of ecological principles and ideas in the simplest and clearest possible manner. Foresters, especially when discussing silvicultural matters, inevitably enter the sphere of ecology, silviculture being largely applied ecology. It is of the greatest importance that thought shall be clear and accurate on such matters; but this is not possible unless those whose duty it is to develop the fundamental science express themselves in a manner which is clear and understandable to those who apply it.

Reconnaissance Surveys. Ecological reconnaissances are probably of particular importance in forestry at the present time. In forest administration it is necessary to make decisions within a short time; the results of long-term research cannot be waited for. Such decisions, made before the ultimate results of long-term research are available, need to be based on adequate working hypotheses if unduly large errors are to be avoided. Reconnaissance has the function of discovering the nature of the problems awaiting solution and with which administrative activity is concerned, and of formulating working hypotheses as to their probable fundamental explanation. In this way relatively well-informed and certain action can be taken while the results of long-term research are awaited.

It is plain, also, that if any survey of the potential suitability of land for agriculture or forestry is to be made, as suggested by Dr. Dudley Stamp, it must be begun as a reconnaissance, for a detailed survey of the whole of Britain would take too long when the purpose of the survey which is of first importance is to provide data for administrative action in the immediate future. The need for the carrying out of such a reconnaissance survey in accordance with statistical principles, the need for which in ecology was stressed by Dr. Blackman, must be obvious.

Autecological Studies. A number of speakers stressed the need for these. This need becomes very plain if the pathology of any species of tree is considered as a whole. It is not possible to understand the causes of health and disease in the

case of any particular species, without understanding or at least attempting to obtain a conception of the autecology of the species concerned. For health or disease is the result of the interaction of factors of the environment on an organism of a particular constitution. Ultimately this constitution and the physical and biotic factors concerned must be understood if a perfect realization of the laws determining health and disease is to be obtained. An autecological study should thus aim at presenting a view of the whole of the physical and biotic relationships of a species.

The concept of fertility might well be developed in connexion with autecology. A particular strain of any species will obtain its optimum development in a particular physical environment and in association with particular plants and animals. Any departure from the optimum will involve corresponding variations in the environment. One is defining the fertility of the sites concerned in defining growth after this manner. This is, I feel, a matter of considerable importance to foresters whose great difficulty very often is to see the wood for the trees.

Soil Studies. A number of speakers expressed the importance of soil studies in ecology. As a pathologist I feel there is need to stress this at the present time. The environment of the root of trees, and the growth of roots in relation to this, is inadequately understood. The mycorrhizal studies of Dr. Rayner, the various forms of deficiency disease, the difficult and complex problems involved in the root diseases of the larger trees have only to be mentioned in order to realize this. These are all involved in the problem of fertility, mentioned above, if any fundamental view of the matter is taken. The need for understanding the range of variation in soil conditions is also to be stressed.

DR. A. J. WILMOTT.

Dr. Wilmott, speaking as a systematic botanist, stressed Dr. Clapham's plea for the preservation of a sufficient amount of our natural vegetation. The laboratory of the systematist was, he said, natural vegetation in which the distributions of species and forms could be studied, for data of distribution were his fundamental facts. The interference resulting from all this planning, planting, and other economic activities was as if someone went into a chemist's laboratory and started throwing the bottles about and smashing them. He hoped that some of the real ancient woodlands—and as a systematist he could say from the species in the woods which were real old woods—would be spared. He agreed with Professor Osborn that in this country there were different edaphic climaxes; he could not understand how any field botanist could treat all our woodlands as parts of a single climatic climax. As an example of avoidable failure in planting he referred to his observation in Yorkshire of a dale bearing fine old beechwood on one side of a valley and a cleared slope on the opposite side planted with small conifers—all soon dead. He thought that any ecologist might have been able to foretell that result, but who was responsible he did not know. He referred to the presence of woodland species on the lower rock ledges of Beinn Laoigh, and forest timber in the neighbouring bogs, as in so many parts of Scotland, even on cols high up, which suggested that timber could be grown in quantity to-day in

Scotland, although possibly these woodlands might belong to a period of different climate and their absence to-day be due not merely to the prevention of regeneration by browsing deer. (The main thing, from the systematist's point of view, was that the data concerning exactly what has been planted, and where and whence, should be preserved in an available form, so that the discovery of fresh species in any area could be interpreted with some degree of probability or certainty, as being perhaps a rare overlooked species favoured by the changed conditions, or as a definitely introduced plant, brought in with such and such a species from such and such a place in which it was known to occur. These data should be preserved even if their usefulness to the forester had passed, and would gladly be kept at the Natural History Museum.)

The Chairman, in calling upon Sir Roy Robinson to reply to the important issues raised during the meeting, remarked on the unfortunate lack of reference to the role of the smaller animals in preserving the conditions of woodland habitats. Quite apart from the woodland pests, on which many adequate studies have been published, the general invertebrate fauna comprises important sections of forest communities, of which we have all too little knowledge. It is to be hoped that this gap will ultimately be filled, to the mutual benefit of foresters and ecologists.

SUMMING UP—SIR ROY ROBINSON.

I have listened with care to the whole of this discussion. It is scarcely possible for me to cover it all in the time that remains, and therefore I will confine my remarks to two or three points.

In the first place I do not assess my two working hypotheses as 'rules' to which foresters should adhere, but merely as lines of thought which in the event may or may not turn out to be correct, but in any event can serve to focus attention on what are undoubtedly important issues.

Then I do not want to infer with regard to the silvicultural stream that it is desirable in every case, or even in most cases, to go the whole course. As Professor Champion points out, it may be necessary to remain anchored or occasionally to work up-stream. What I do think, however, is that in both cases explanations of some of the difficulties which then arise may be sought in the theory of ecological successions.

I agree as to the necessity for laying down ecological reserves. The Forestry Commission in association with ecologists have already made a beginning and are prepared to go further. To get the full value out of reserves it will be necessary to undertake and periodically repeat a great deal of descriptive work. The Commission can and will afford the facilities, but foresters have not the time to spare from routine duties nor the specialized training. I trust, therefore, that the Society will formulate its ideas in some detail so that the venture may go forward smoothly. I hope too that the problems will be regarded, as our Chairman has pointed out, as not only botanical but also as biological in the widest sense of the term.

BEATING UP BLANKS IN NEW PLANTATIONS

BY W. L. TAYLOR

NO matter how much experience is brought to bear in establishing new plantations, foresters cannot always secure complete stocking as a result of the first planting. Losses occur in the best regulated plantings, and there are many reasons to account for deaths among newly planted trees, including simple failure on the part of transplants to withstand the shock of the final setting out in the forest. The remedy is to do everything good silviculture can do to avoid loss, but, care and skill notwithstanding, young trees will die on occasion, and, where the number and distribution of failures justify it, blanks in plantations require to be made good. The operation of filling spaces occupied by trees which have died is known as *beating up* the plantation. To achieve the ideal of even stocking and to facilitate after-management, new plantings are usually made to conform to an orderly design. Trees are commonly planted in rows at regular intervals, each tree being planted equidistant from its neighbours on all sides. Regularity of espacement is sometimes varied as, for instance, in the case of oak which may be planted more closely together in the rows, but basic arguments relating to beating up are not affected by the geometrical pattern to which the young trees have been planted except that beat-up plants should not be put into places where they will complicate subsequent silvicultural operations.

Where losses warrant it, plants and labour are assigned to beating up in order that a plantation shall start away reasonably full and that the trees be enabled to close in evenly and form canopy with as little delay as possible, to suppress side branches and weeds and to protect the forest soil. Adequate stocking is also essential from the point of view of forest finance because the aggregate of gaps in a wood, unless filled up betimes, represents land which will remain unproductive throughout the rotation, or for an appreciable part of it even where underplanting is a promising proposition at a later stage. Neglect to attend to necessary beating up in proper season inevitably reacts upon Expectation Value, the non-employment of any part of an afforested area being an obvious source of waste leading to reduced yields from thinnings and detracting from the possible maximum volume of the final crop. Other silvicultural troubles follow uneven stocking: too much growing-space for individual trees induces a coarse habit of growth, and gaps or 'holes' in the canopy may, in some situations, be an invitation to disaster from gales. Filling blanks necessarily adds to cost of establishment, but, where deaths occur, the pros and cons of beating up must be considered. On the one hand the welfare and productive capacity of the plantation are at stake, and on the other, an increase in initial cost is involved and it is a duty of the forester to keep cost in bounds. To plant beat-up plants costs more per plant than ordinary, straight-forward planting chiefly because of the greater area a man has to range over to put in a given number of plants and because of the more

careful consideration which should be given to the siting of each replacement. The extra transplants used, and extensions of the weeding period, have also to be counted into total cost.

Losses in young plantations are often due to errors in assessing soil qualities and factors of locality and in selecting species. Much depends on the quality of the plants used, and undersized, weakly, or badly rooted plants, or plants which have developed shoot and foliage beyond the capacity of root absorption to balance transpiration, always carry with them the possibilities of disappointment. Careless handling of nursery stock with damage to rootlets and bruising of stems; exposure to frost, desiccation, or spontaneous heating in transit to the forest; neglect to untie bundles and to heel in the plants properly on arrival and to keep roots moist, are, with unskilful planting, the chief faults militating against a good 'take'. Success is strongly influenced by conditions at the time of planting, and, on the whole, it may be said that the forester who produces an even plantation, approaching 1·0 stocking, at first intention, is entitled to congratulate himself, although with reasonable precautions and a modicum of good fortune in regard to weather, this happy result is not by any means an impossible consummation.

Apart from other considerations, the fundamental object in view in completing a plantation by beating up is to ensure such distribution of thriving trees that, in due course, a correct number of well-grown stems can be selected to stand for the final crop. This can only be done if the plantation is full enough to begin with to allow of ultimate selection at regular spacing. It follows, therefore, that beating up cannot be dispensed with unless previous losses are light and evenly distributed. Where these conditions obtain, and deaths do not exceed 10 per cent. or so, it is possible to ignore the failures, but, if trees die in groups or patches and if the losses amount to more than about one in ten, the resulting blanks should usually be made good. Replacements need not necessarily be tree for tree, neither need the beat-up plants be sited precisely in the same places in the rows as the plants which have died, or at the identical espacements of the original planting. In other words, replacements need not always represent 100 per cent. of the deaths. Single failures can be left blank, if not too numerous, and, if two or more consecutive plants come to grief, two failures can be replaced by a single tree planted midway between the living plants on either side of the gap. In like manner, three deaths can be replaced by two fresh plants, but, where failures follow one another in a more lengthy sequence, it is advisable, if beating up is done within reasonable time, to complete the rows. Similar principles can be adopted in filling up group failures, but beat-up plants ought not to be inserted anywhere out of alignment with the original rows or they will add to the trouble and expense of future weedings.

Before any plant is replaced as a failure it is necessary to be sure of two things: firstly, that it has failed beyond hope of recovery, and secondly, that the beat-up plant will have a reasonable opportunity of entering the canopy and taking a useful place in the stand. Signs of failure are obvious with some species, but spruces, and less frequently Douglas fir, sometimes survive and flourish after a period in which, to all appearance, they are moribund or quite dead. Indications

PLATE I

MORTIMER FOREST 1943

P. 26 Douglas fir, beaten up P. 30 with Scots pine showing (1) the wasteful planting of a beat-up tree next to a plant not actually dead, (2) the futility of using a slower growing species for beating up.

SWAFFHAM FOREST 1943

P. 24 Corsican pine, beaten up P. 31. The stem of the suppressed beat-up tree in the foreground has been peeled to make it more visible.

of death are more conclusive with pines and larches, although European and Japanese larch, if bitten off by rabbits or hares, often break away again from semi-dormant buds around the collar of the plant. For one reason or another, usually drought or frost, broadleaved species are given to dying back, or they may be bitten off by game. Even when killed down to ground level, some of them, oak in particular, also beech and ash, may retain enough vitality to coppice and come away successfully in the following growing season. Patience, so valuable an attribute in the raising of plantations, is an essential quality if unnecessary beating up is to be avoided. To replace doubtfully dead and dying trees is often wasteful; root development may not have been so idle as signs above ground temporarily indicate, and, where there is an active root system, there is great recuperative power. Over-anxiety to fill up blanks may result in a double crop over parts of the plantation, both the original and the beat-up plant continuing to grow side by side. There are two common tendencies: one is to leave blanks unfilled, and the other is to be too thorough and to replace more plants than is needful.

After a pause for self-adjustment to their surroundings it is usual for young trees to begin to grow strongly, the period of initial check varying according to species and circumstances, from a year or two to a good deal longer. Norway spruce is slow and Corsican pine irregular, in making a start. Sitka spruce may also prove slow or alternatively, on favourable sites, free from frost, will go ahead quickly after a short check. Scots pine, Douglas fir, and European larch seldom hesitate for long if conditions are reasonably agreeable, and Japanese larch often begins to grow rapidly after the first season. Broadleaved trees are not consistent, but, as a rule, are not in any great hurry to start away. When vigorous growth commences height increases rapidly, and, at the same time, lateral growth also extends with stealth that is apt to be deceptive; where there is room, side branches widen their spread by less than 6 inches up to 10 inches or 12 inches in a single growing season. The rate at which growth proceeds or is likely to proceed—and trees grow faster horizontally on the edges of gaps—has an important bearing on beating up. It is very necessary to visualize the position of a beat-up plant as it will be a few years ahead, allowing for its habit of growth in comparison with that of the originals. Total height and the height above ground of the widest crown spread, together with the annual rate of growth at present and in the next few years, are points to assess or estimate. The picture should be clear in the mind's eye. Can a beat-up plant, which always starts at a disadvantage in point of time, maintain itself against the continuous encroachments of the older trees? If the answer is not a clear affirmative, beating up will rarely be worth while. The photographs, taken in Swaffham and Mortimer forests in 1943, illustrate the point.

The period and timing of beating up operations are important, and, when losses are unmistakable, blanks should be filled up with little delay because each year that elapses imposes a longer handicap on the beat-up plants. Too many silvicultural factors are involved to make fixed rules possible, and it may be said that while the season after the original planting may not be too early, the work can, on occasion, be done after a lapse of several years. There is also the possibility

that original plants may survive the first year and fail in the second and later years. Rapid growers offer the least latitude for delay, and in all cases the longer the operation is postponed the greater the experience and judgement necessary to determine how far it is economic to replace failures. A quick review of chances is required in regard to space and light, before a blank space is filled, and the longer the original planting has had to establish itself the more caution there should be. Blanks occurring after a plantation has started to grow are chiefly the result of animal pests, fungi, windblow, snow-break, fire, and, occasionally, excessive drought. Unless the trees lost are grouped in sizeable patches not much can usually be done by beating up to remedy belated losses.

The choice of species with which to beat up depends on the extent and distribution of the failures, the stage at which the operation is undertaken, local circumstances, and the species and condition of the original planting. If little time is lost the simplest prescription is to keep the plantation pure. If there has been delay it is desirable that species used as beat-up plants shall be quicker, or at least as quick to start away, as the original species or they must be shade-bearers; shade-bearing qualities in beat-up plants (lateral shade) are desirable anyhow if the original plantation is making good progress. Light-demanding species should be used with discretion for beating-up purposes and slow starters not at all. In matters affecting the filling of blanks, as in other operations of practical forestry, it is important to remember that theory should go hand in hand with experience and observation; procedure in specific cases depends upon whether losses are sporadic or extensive and upon other factors only to be ascertained on the ground.

Some half-dozen or so species possess qualities which render them pre-eminently suitable for beating up. Beech has been utilized widely in the past, being a shade-bearer and a soil improver, but the practice of filling up with a few beech has frequently been overdone. Scots pine is a useful tree for filling blanks in plantations of Norway spruce and of Corsican pine; it is also a good tree to bring in among broadleaved species on the poorer quality classes of soils. Douglas fir tolerates a good deal of shade when young and makes an excellent beat-up plant among European and Japanese larches and Sitka spruce, and, in circumstances of undue delay, in pine plantations. Douglas fir is, for a conifer, unusually resistant to honey fungus (*Armillaria mellea*) and can be used to fill gaps so caused. If Norway spruce is getting well away, blanks may be filled up with Sitka spruce, but the latter is unsuitable for use as a beat-up plant with other species if complications are to be avoided in after-management. Where a particularly quick start must be secured in a beat-up plant, Japanese larch is usually the best choice; it will maintain itself in competition with previously planted Douglas fir and can be brought into plantations of European larch as well as being suitable for beating up Scots and Corsican pines after long delay. Hemlock (*Tsuga heterophylla*) succeeds, where shade conditions exist or are anticipated, among Sitka spruce, Douglas fir, and European larch, but appears susceptible to honey fungus.

Opportunities occur to introduce ash and sycamore singly or in groups, and both these trees often find optimum conditions in sporadic mixture with other

species. Birch, weed species, and singled coppice shoots are acceptable to fill up blanks and should not be cut out indiscriminately if likely to aid in covering the ground or if they can be brought into the crop.

Beat-up plants, equally with originals, are planted with the intention that they shall form part of the crop, and the operation becomes futile where this condition stands no reasonable chance of being fulfilled. Strong plants of good size and quality are required and they must be well planted; experienced and reliable men should be entrusted with the work and supervision must be diligent. Failures must be positive before action is taken to replace them; the sound rule is to beat up within a reasonable time and not to use badly grown, weakly plants for the purpose. The fact that delay of several years is sometimes allowable often spreads a snare for the unobservant, and in spite of the latitude the nature of the problem affords, there is a limit to permissible delay in all cases. Beat-up plants must be able to get away with the least possible check, if for no other reason than because extensions of the weeding period are tedious and expensive.

THE CONE PRODUCTION OF SCOTS PINE SEED-BEARERS

BY E. W. JONES

IT has long been taught and generally accepted that in natural regeneration only the best trees should be left as seed-bearers. While the consideration that defects of any sort may be the expression of inherited characters is the most fundamental reason for this teaching, the necessity for abundant seed despite a reduced number of trees, and resistance to damage by storm and disease, are equally important in many methods of regeneration. Under present conditions in this country there is obviously a great temptation to set aside such caution as being unnecessarily pedantic, and the fact that this view has been acted on to some extent makes it worth while placing on record some observations, however imperfect, made in Busketts Lawn Inclosure in the New Forest during the years 1941–3.

In the New Forest many of the fellings in the pine crops since 1939 have been made with the object of regenerating by the shelterwood-compartment system. In the earliest fellings 12–15 seed trees to the acre were left. In fellings made in the south of Busketts Lawn Inclosure in 1940–1 rather more trees—probably about 20 per acre—were left. The trees though of large size were of poor form; most of them had probably been dominants in the original crop. In the following season the danger of retaining badly shaped trees was realized and in regeneration fellings in the north of the inclosure about 24 trees per acre of good form were retained; they were, however, smaller stems which had probably been codominants or even subdominants in the original crop. This difference in size of tree is illustrated by the following figures for girths taken at random in the two areas.

Girth class	*Below 40 in.*	*41–5 in.*	*46–50 in.*	*51–5 in.*	*56–60 in.*	*Over 60 in.*	*Total*
South of inclosure, two samples (felled 1940–1)	1	0	3	3	8	5	20
	0	0	3	5	4	4	16
North of inclosure (felled 1941–2) . . .	4	10	2	4	0	0	20

In July of 1942 and 1943 estimates were made of the cone production of these trees. The cones which will mature in the autumn are then bright green and nearly full sized, and thus very conspicuous. The crowns were examined with binoculars, and, using a purely arbitrary scale, were classed as having cones abundant, frequent, or occasional. Care was taken to use these classes with reference to the density of cones on the crown, and not to their absolute number.

At the same time the probable status of the tree in the former stand was recorded (dominant, codominant, or subdominant). The subdominants were few in number and formed at most a tenth of any sample. The methods are admittedly crude, and it is likely that the standard of abundance used varied from time to time, but the figures should be consistent within any one sample. The results are given in Table I. Five samples are available, representing different years and different parts of the crop. In addition there is one sample (vi) from an area where clear-felled strips 100 feet wide alternated with unfelled strips 60 feet wide.

TABLE I. *Number and percentages of pine classified according to abundance of cones and class of tree*

	Abundant		*Frequent*		*Occasional*		*None*		*Total*	$\chi^2_{[1]}$	*P*
	No.	%	No.	%	No.	%	No.	%			
I. 1942 North d	5	63	2	25	0	0	1	12	8	4·20	0·02–0·05
cd	1	8	4	33	5	42	2	17	12		
Total	6	30	6	30	5	25	3	15	20		
II. 1943 North d	2	33	1	16	2	33	1	16	6		
cd and sd	2	8	4	17	7	29	11	46	24	1·7	0·1–0·2
Total	4	13	5	17	9	30	12	40	30		
III. 1943 South, western part d	0	0	1	10	7	70	2	20	10		
cd and sd	0	0	3	30	2	20	5	50	10	1·98	0·1–0·2
Total	0	0	4	20	9	45	7	35	20		
IV. 1943 South, eastern part d	4	29	6	43	4	29	0	0	14		
cd and sd	0	0	1	17	2	33	3	50	6	5·08	0·02
Total	4	20	7	35	6	30	3	15	20		
V. 1943 South, northern part d	1	12	4	50	3	38	0	0	8		
cd and sd	0	0	2	17	4	33	6	50	12	4·43	0·02–0·05
Total	1	5	6	30	7	35	6	20	20		
VI. 1943 Strip fellings d	7	26	12	45	6	22	2	7	27		
cd and sd	1	4	7	30	10	43	3	13	23	5·10	0·02–0·05
Total	8	16	19	38	16	32	5	10	50		
Total of samples I–V d	12	26	14	30	16	35	4	9	46	$\chi^2_{[3]}$	Much less than 0·01
cd and sd	3	5	14	22	22	31	27	42	64	20·59	
Total	15	14	28	25	36	33	31	28	110		

d=dominant. cd=codominant. sd=subdominant.

In every one of the six samples there is evidence that the former dominants are coning more heavily than the codominants and subdominants. The difference is, moreover, often very considerable, as in sample I where 63 per cent. of the dominants have 'abundant' cones, whereas only 8 per cent. of the codominants come into this class, and 59 per cent. of these have 'occasional' or 'no' cones. Cones were classed as occasional when not more than three or four could be seen on the whole of the face of the crown examined; the amount of seed from such trees will be negligible. That this difference should occur consistently in six samples is itself so striking that further statistical examination is scarcely necessary, each sample has, however, been treated as a contingency table and the distribution of cones among the dominants and co- plus subdominants tested for homogeneity by calculating χ^2. The values of χ^2 and the corresponding probabilities are included in the table. The numbers in each sample are small, and it has been necessary to treat each as a 2×2 contingency table with only two classes of cone frequency, but in four of the six samples the probability of the difference between the dominants and the codominants being due to chance variations is less than 1 in 20; taking all the five samples from the shelterwood regeneration areas together, the probability is far less than 1 in 100. It is thus quite clear that the codominant trees do not make satisfactory seed-bearers from the point of view of seed supply and that the leaving of a rather larger number of the smaller trees is not equivalent to leaving the best of the dominants. In addition, it may be noted that there has been considerable loss from storm damage and beetle attack amongst the smaller trees of the areas felled in 1942, and very little such loss among the bigger trees of the 1941 regeneration area.

One further point is of interest. The seed crop was heavy in 1940 (seedlings of 1941) but has been very poor both years since. In comparing cone production by the trees in the intact strips (sample VI) with that by the seed trees in the shelterwood areas in 1943 (samples II–V) it is clear that cone production by the latter is markedly poorer. This depression of seed production following isolation of seed trees might be an important point in favour of strip methods of regeneration. But it also emphasizes the importance of retaining the most prolific trees for seed-bearers, since conditions for quick and abundant seedling establishment are at their best during the year or two immediately following the felling, when there is still little competing vegetation covering the ground.

SUMMARY.

Assessments of the cone production of Scots pine seed-bearers in Busketts Lawn Inclosure, New Forest, in 1942 and 1943 show that the former dominants produce more cones, relative to the amount of crown, than former codominants or subdominants. The isolation of seed-bearers in the shelterwood regeneration felling is followed by a depression in cone production. It was observed that there was a greater accidental mortality among the former codominants than among the former dominants.

SOME OBSERVATIONS ON HEART ROT IN CONIFERS FROM AN ECOLOGICAL POINT OF VIEW

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THE present brief outline is the result of survey work done during 1942–3 as far as conditions of travel and time permitted. Apart from Tynninghame Wood, woods near Spott (Dunbar), and the Penicuik Wood, all others lay in the Tweed valley between the Peebles district and Holylee, about 2 miles east of Walkerburn. The woods in the Tweed valley were Quarry Wood (Peebles), Kirkton Manor (Peebles), Drove Road West (Peebles), Venlaw (Peebles), Glentress (Peebles), Plora (Innerleithen), Dod Hill (Traquair), Fingland Burn (Traquair), Holylee (Walkerburn). Dunbar has an ordinary soil, but at Tynninghame sand from sand-dunes covered much of the subsoil (or rock). In the Tweed valley the underlying rock was Upper Silurian. The soil conditions were remarkably similar in spite of differing exposures. Elevation in the Tweed valley varied from 500 to approximately 1,500 feet.

The botanical survey was carried out by a general survey of each wood to assess the vegetation, and then traversing the wood by a series of parallel lines to note the trees, the incidence of heart rot, and how it varied with altering vegetation and other factors. Where any particular type of vegetation showed a definite increase in heart rot, that part was examined, the total number of trees counted, and the proportion diseased calculated as a percentage. It must be pointed out that after felling it is often quite impossible to be certain that all stumps have been located and therefore figures must be regarded as approximate only.

It has been known for some time that heart rot was expected where trees were planted on farm land or soil which had been used for agricultural purposes. There are many strange beliefs concerning this disease or diseases, but all proved to be erroneous. No attempt was made to culture out affected timber to identify the exact fungus. In Scots pine at Tynninghame fructifications were found of *Polyporus Schweinitzii*, and near Spott (Dunbar) *Fomes annosus* was found on spruce. From these it may be deduced that the former fungus was the cause of heart rot in Scots pine and the latter in spruce, since the symptoms and appearance were similar in all parts surveyed. Our main concern, however, was to try and correlate any heart rot with vegetation types. Throughout the parts visited in the south-east of Scotland during 1941–3 heart rot was common and widespread. The trees affected were spruce, Scots pine, and larch. Of all trees Norway spruce was the most susceptible. In Scots pine and larch the proportion of trees affected was generally small, although at some places the proportion showed rather wide fluctuations. Usually the effect of heart rot was remarkably similar in all trees attacked, and as the name suggested it usually commenced at the root system and slowly worked up the centre of the heart wood. This was

not universal, for sometimes it commenced as a small spot at one side and then spread towards the centre until the centre was completely destroyed. In a few cases heart rot arose at or near the surface and suggested external injury. In one place heart rot was found in the outer rings, while the first 50 rings of growth were perfectly sound. This suggests injury, as all the trees formed a group (spruce). Yet in the same wood other spruce trees had the typical form of heart rot. Heart rot frequently seemed to commence in Scots pine after the age of 100 years had been passed. This of course may be linked up with age and soil conditions. Heart rot, however, was found in Scots pine of 70–80 years. Spruce showed a peculiar feature in some woods where the younger trees (50 years or less) had a much higher incidence of heart rot than those of 70 or more. Generally, however, it was the older trees which were chiefly affected. It is quite possible that certain of the younger trees died years ago and left no trace. Larch followed the general rule in that the older trees were mostly affected. Douglas fir was too infrequent to form any real opinion, although those seen were healthy.

Comparing the incidence of heart rot with vegetation types, there were definite correlations. At Tynninghame Wood, where the heaviest damage by heart rot was found, there was a definite correlation with the presence of the moss *Leucobryum glaucum*. Where the patches were large and plentiful there the damage was most extensive. This was also noted at Letterbox Wood (Peebles) and Yarlside (Earlston). In the majority of woods the grass known as creeping soft grass (*Holcus mollis*) occurred in patches. Wherever this grass occurred there was a definite increase in the incidence of heart rot. The increase varied in different places and in different woods. In quite a number of samples the incidence of heart rot rose to 30 per cent. of the trees within or near *Holcus mollis*. Where bent grass (*Agrostis tenuis*, chiefly) reached a locally dominant position in the vegetation, heart rot again showed an increase, but it was not so marked as that for *Holcus mollis*. Another plant which often dominated the vegetation in places was the male fern (*Lastrea Filix-mas*) and its near relative *Lastrea dilatata*. Where this occurred there was a slight but definite increase in the incidence of heart rot. The woods near Spott (Dunbar) had a general incidence of heart rot, but it was not particularly high. This was probably due to the fact that the situations chosen were naturally well drained and there was usually a deep permeable soil. The weed flora following the removal of the trees was that of arable land. In fact the coniferous woods examined were planted on reasonably good agricultural soil. But for good natural drainage the losses might have been very heavy. The Dunbar area generally is essentially non-coniferous. The growth of beech, oak, &c., shows this very clearly.

Another factor which cannot be ignored is that in several woods sheep had broken in or had obtained access. In a few places they regularly used the wood for shelter as well as grazing. This, of course, brings the wood virtually into the condition of agricultural land. The grazing and dunging of sheep promoted a grassy type of undergrowth, where the wood is sufficiently open, and in consequence the condition soon approaches that of a fourth- or even third-rate pasture rather than of woodland.

Taking the woods generally in the Tweed valley, the natural vegetation would normally be of the heath type dominated by heather (*Calluna vulgaris*). As the result of burning, grazing, and other activities this vegetation has been modified till in some places it has assumed a grassy type. Where not actually controlled for farming purposes it is rough grazing with bracken, blaeberry (*Vaccinium Myrtillus*), wavy hair grass (*Deschampsia flexuosa*), bent grasses (*Agrostis tenuis*, chiefly), sheeps' fescue grass (*Festuca ovina*), Yorkshire fog grass (*Holcus lanatus*), and in open woods and shady places creeping soft grass (*Holcus mollis*). There are a considerable number of other plants typical of such an area, but which do not usually bulk largely in the ground cover.

DISCUSSION.

It is evident that the moss *Leucobryum glaucum* is of value as a danger signal that Scots pine planted on such land is likely to become seriously affected by heart rot. Judging from what has been observed at Tynninghame, Letterbox, and Yarlside woods, the last-named near Earlston and not in the Tweed valley, the amount and size of the moss cushions appear to be correlated with the nature and extent of heart rot in Scots pine. Where *Leucobryum glaucum* occurred the trees were Scots pine, and, so far, we have no experience or information as to whether there is any correlation between the presence of heart rot in larch and spruce and this moss. It would be rather surprising if these trees do not react as does Scots pine. The moss has a fairly wide distribution, and further information can be obtained in Tansley's recent book (2). In rough grazing it occurs where there is excessive surface water which cannot percolate through the dead undecayed vegetation mat covering the surface soil. It also tends to occur where acid water soaks downhill from wasting peat at higher levels. This, of course, would tend to render the soil waterlogged and adversely affect the root system. Again, where the water level is unduly high, a similar state of affairs could arise as far as the root system is concerned. Where underlying rock or any impervious layer retained the water in depressions in the soil level, there the incidence of heart rot showed an increase. Such increases were naturally irregular and patchy, but it was generally quite evident that excessive water was a contributing factor to disease. The mere presence of water is not necessarily a danger, provided it is not stagnant and that the soil drainage is satisfactory. This was well illustrated at the Penicuik Wood, where in spite of much water and *Sphagnum* moss, drainage ditches were still operating and in consequence the water was fresh. Heart rot though present had a low incidence.

The correlation between increase in heart rot and the presence of patches of *Holcus mollis* is most interesting. It was seldom that the proportion of trees affected by heart rot rose above one-third of the total, but the increase was very definite, not merely within the part dominated by *Holcus mollis*, but also around the outer fringe. This grass is not generally typical of natural or semi-natural coniferous woods, but it is common in most non-coniferous woods. It would appear that in parts of the Tweed valley conifers have been planted where previously mixed woods or non-coniferous trees had grown. Even to-day some

of these non-coniferous trees still grow mixed with conifers. The grassy covering is often associated with the presence of these non-coniferous trees whether the grass is *Holcus mollis* or *Agrostis tenuis* or both. The grasses most commonly associated with coniferous woods, where grass exists, is *Deschampsia flexuosa* and, to a much smaller extent, *Festuca ovina* and *Agrostis* spp. If these patches of grass are considered and judged on what might be roughly termed agricultural standards, then they can be placed in certain definite positions in the classification of permanent pastures (1). Where bent grasses predominate this suggests a third-class or fourth-class pasture. Where *Festuca ovina* and *Deschampsia flexuosa* are more frequent the category is distinctly lower, approaching that of a heath. *Holcus mollis* is rather difficult as it is not commonly an important constituent of typical pasture. It does occur in rough grazings in the south-east of Scotland where whin or gorse (*Ulex europaeus*) grows, or where formerly non-coniferous trees grew. After burning of whin, *Holcus mollis* temporarily occupies the ground and often lingers on long after the bushes have died out. Assuming, however, that its position is rather similar to the far more ubiquitous *Holcus lanatus*, generally known as Yorkshire fog, then it can be placed quite readily as a common component of certain third- or fourth-class pastures. Hence it would appear that, judging by agricultural standards not only is phosphate and lime getting low in the soil but also the available nitrogen. When we pass from a third to a fourth class or lower, the fall in the value of these in the soil is still more marked, and reflected usually in the vegetation. In other words, in the third class we are approaching the agricultural land standard and its known effect on the incidence of heart rot.

In the wood near Kirkton Manor the incidence of heart rot was in places not merely high, but many of the trunks were so hollowed out as to be quite useless. In this wood sheep had broken in and both dunging as well as grazing had occurred over a rather long period. The grass had that deep luscious appearance so evident where excessive nitrogenous manuring has been applied. In the parts most affected *Deschampsia flexuosa* had been dominated not so much by *Holcus mollis* as by *Agrostis tenuis*. In other words, agricultural practice had been introduced into woodland. From this it would appear that nitrogen, if present in any quantity in the soil, is not satisfactory for coniferous trees, for not only was spruce affected but also Scots pine and some larch. At one part of Plora Wood (near Innerleithen) at a part of the top next a wall, protecting it from the hill-side, over one-third of the spruce was affected by heart rot. The rough grazing outside had, next to the wall, been altered by the sheep treading, grazing, and dunging to a bent grass type of pasture (third class). This is approaching the Kirkton Manor Wood condition. Then at Holylee South Copse heart rot occurred almost entirely at the perimeter of the wood. On the upper side the sheep had produced a bent grass type of pasture from the rough grazing, as at Plora Wood. The slope of the land would tend to make soil drainage move towards the roots of trees next the perimeter of the wood. On the lower side a rotation pasture was present, and here also heart rot was evident. The slope, however, was downwards away from the wood, otherwise heart rot would probably have been much worse. This

is the nearest approach to arable land so far recorded. Hence it would appear that the presence of grasses such as *Holcus mollis* and *Agrostis tenuis* in any quantity suggests a higher state of soil fertility, judged by agricultural standards, than where these grasses do not occur or are comparatively scarce. It is probable also that nitrogen above a certain figure may adversely affect the mycorrhiza of coniferous tree roots. Where heather (*Calluna vulgaris*) is dunged by sheep, especially if this continues for some time, it dies out. This is generally considered to be due, among other factors, to its effect on the mycorrhiza. Heavy nitrogenous manuring can also adversely affect clover plants as it depresses the activity of the bacteria in the root nodules. In some of these woods, stinging nettle is not only present but spreading. This does not suggest a very low fertility.

The only other example of an increase in heart rot, and not very marked, was where *Lastrea Filix-mas* and *Lastrea dilatata* dominated the floor of the wood. This usually occurred where the soil was rather moist, but these ferns are also at times associated with rather better soil conditions.

One very important point is very evident. In spite of the increase in the incidence of heart rot where certain types of vegetation or plants occur, the majority of the trees were usually healthy. Certainly there were always some sound trees. This leads one to suspect that there are strains of conifers which are resistant to heart rot, in spite of rather adverse conditions. If these strains could be successfully isolated, much of the loss incurred might be avoided. But, in isolating such strains for seed purposes, care must be taken to see that resistant strains produce as good quality timber as the less or non-resistant strains. Undoubtedly both seed and plants have been purchased in the past without regard to pedigree or strain. Often cheapness was the chief consideration. The result is such to-day that it would be incredible if such methods were not forbidden in the future afforestation of Britain.

There was some evidence at Quarry Wood (Peebles) and at Spott Burn Wood (Dunbar) that heart rot was more prevalent where rabbits had burrowed beneath the roots of the trees. At Spott Burn Wood, *Fomes annosus* was found in full fructification on the underside of a spruce root system. This naturally raises the question as to the relationship, if any, between the intensity of heart rot and the size of the rabbit population.

Two, and only two, trees were found where the wood affected by heart rot had been successfully sealed off by an exudation of resin, thus arresting the disease and killing the fungus.

It should be kept in mind that these findings may not be of universal application. Moreover, there were times when one regretted the absence of a forester and a soil chemist to give expert advice or check up certain points as they arose. But the present survey may assist to indicate the direction in which further efforts may be most needed. From past experience, a small team of workers, at least a forester, an ecologist, and a soil chemist, with the assistance where required of a mycologist and an entomologist, is very satisfactory for this type of investigation.

In conclusion we wish to record our indebtedness to Professor H. M. Steven for much helpful advice, to H.M. Forestry Commission (Edinburgh), and to

Mr. George Walker (James Walker & Co., Leith) for supplying information as to places where heart rot had been found, and to Mr. K. St. G. Cartwright for fungus identifications and verifications.

SUMMARY.

The moss *Leucobryum glaucum* is correlated with the presence of heart rot in Scots pine.

Stagnant water or waterlogging of the soil increases heart rot in conifers, but where the water is fresh and drainage satisfactory the incidence of heart rot is low.

Where the grass *Holcus mollis* is locally dominant heart rot shows a definite increase. This is true to a lesser extent where *Agrostis tenuis* becomes plentiful.

Dunging and grazing by sheep increases heart rot, and it would appear that certain grassy vegetation types, e.g. *Holcus* and *Agrostis*, approach an agricultural standard of fertility near to that recognized as causing heart rot in conifers planted on agricultural land.

There is a slight increase where *Lastrea* ferns become locally dominant.

The fact that healthy trees, often in the majority, occur within the danger area suggests that there are strains of conifers resistant to heart rot, and that these should be developed as a counter measure.

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THE DEPLETION OF STARCH FROM TIMBER IN RELATION TO ATTACK BY *LYCTUS* BEETLES

V. *The Effect upon Starch Content of Storing Timber in the Log*

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INTRODUCTION.

IN the first paper of this series (7) four methods were mentioned by means of which timber might be rendered free from starch and thereby immune from attack by *Lyctus* Powder-post beetles. Subsequent contributions (4, 5, 6) have dealt with the possibility of producing starch-free oak sapwood by girdling standing trees. In the present paper the depletion of starch from timber stored in the round under laboratory and commercial conditions will be considered. The experimental data are discussed in relation to normal commercial practice and no account is taken of the special problems arising in war-time.

The preparation of timber free from starch, with the object of avoiding subsequent insect infestation, was first suggested as a commercial possibility by Mer (2, 3), who recognized that the cells of newly felled trees continue to live and respire and in so doing use up their food reserves, so long as the wood retained sufficient moisture. He pointed out that storage in the log favoured fungal stain and decay—'Pour éviter la vermoulure, on risque d'obtenir la pourriture'—unless precautions were taken to store logs under cover on skids and in a good circulation of air. Wilson (8, 9), experimenting chiefly with small pieces of ash branchwood, has given additional data upon the rate of disappearance of starch and upon the theoretical distribution of residual starch in sawn timber. Henderson (1) has briefly discussed the relationship between temperature and rate of starch depletion from ash and shown that an optimum exists in the region of 41° C.

PRELIMINARY EXPERIMENT.

A preliminary experiment to confirm that starch could be resorbed in felled timber was started in November 1932, when a 3-foot length of a newly felled oak log was left in the open air after having the cross-cut ends coated with gloss oil in order to retard drying. Examination in the following March showed that depletion of starch had occurred in the two outermost annual rings only, but by July most of the starch had disappeared from the outer 10–12 rings. At this time the sapwood showed the first signs of decay by the fungus *Stereum hirsutum*, and no further observations were made, for the object of the experiment had been achieved.

[1] Now at Pest Infestation Laboratory, London Road, Slough.

EXPERIMENTS WITH BRANCHWOOD.

In December 1933 branchwood 3–4 inches in diameter from a newly felled oak was sawn into fifteen 10-inch lengths and the cut ends were immediately sealed with petroleum jelly followed by a coating of paraffin wax. The blocks, consisting entirely of sapwood, were kept in the laboratory at a temperature of 60–65° F. It was anticipated that their rate of drying with the bark intact and the ends sealed would be very slow. One sample was examined for starch content at the start of the experiment and another was cut up at each monthly interval for the next 14 months. After trimming off the sealed ends a slat 1-inch in thickness was sawn from the centre of each piece, planed, and dried rapidly over a radiator in order to fix the starch for future examination. Subsequently the slats were cut in half transversely, one half being examined for starch content and the other exposed to infestation by *Lyctus brunneus* beetles.

Starch was abundant at the start and remained so until April. In May the xylem parenchyma of the outer 8–10 annual rings showed definite signs of depletion, whereas the rays in the same region were apparently unaffected. In June a reduction in the starch content of the peripheral ends of the rays was observed. By October, after which there was no further change, the starch reserves of the outermost 20 annual rings had been resorbed but tissues containing abundant starch were still visible towards the centre of the sample. The moisture content of the sample which had been sealed for 14 months was found to be 25·9 per cent. (based on oven-dry weight). Little is known of the survival of living cells in timber in relation to water content, but it would seem that about 30 per cent. is the order of the limiting value of mean moisture content of the wood for continued life of the cells. It is therefore reasonable to assume that depletion ceased after 10 months as a result of drying of the experimental samples. Death of the cells leads to fixation of the remaining starch.

A year after exposure to *Lyctus* infestation, exit-holes were observed in the control piece and slats 1–8. The remaining slats showed no exit-holes, although small areas of starchy wood were in all cases powdered. None of the samples showed any trace of fungal decay.

Similar experiments were started with ash and walnut branchwood in February 1934, but the samples were kept out of doors under cover. In the ash, in which a moderate amount of starch was present initially, depletion was first apparent in May and almost complete by October, after which no further change was visible; no fungal stain was observed. Exposure to *Lyctus* infestation resulted in the appearance one year later of exit-holes in the control and the first four of the monthly samples. In the walnut, which was also moderately starchy, depletion was just evident by April and progressed rapidly until August, when the wood was starch-free. A greyish stain appeared in the outer sapwood during the third month and spread quickly, until, after 8 months, the samples were discoloured throughout. *Lyctus* infestation developed in the control and first four experimental samples.

The conclusions drawn from these small-scale experiments were that oak and

ash were likely to be amenable to a starch depletion treatment involving log storage, and that difficulty might be experienced with walnut, owing to a discoloration which appeared concurrently with or soon after the start of depletion: such a stain might not, however, be important commercially. In addition, depletion occurred fairly rapidly at summer temperatures and was negligible during the colder months in those samples kept out of doors.

EXPERIMENTS WITH LOGS.

Ash

In March 1936 a 6-foot length of a newly felled ash log with the bark intact was creosoted on the cross-cut surfaces and stored on skids in an open-ended shed. An increment boring showed that starch was present in the tissues of the outermost annual rings to a depth of about 2–5 inches. The log was sawn into 1-inch boards in February 1937, after storage for 11 months, when the timber proved to be bright and clear with no sign of decay or discoloration. On planing the boards and applying iodine solution it became evident that almost complete depletion of starch had occurred during storage. That which remained was present in too small a quantity to allow development of *Lyctus* larvae, except in a narrow strip about 0·5 inch in width on one side of the log.

On 12 January 1937 borings were taken from 7 recently felled unbarked ash logs stored on skids in the open at the Laboratory. The starch grades of the youngest 25 annual rings of each boring were recorded by the method described by Phillips (7). Comparison with a second set of borings taken on 1 October showed that some depletion of starch had taken place in every log during the 8½ months' storage, but more rapidly at the outer parts than towards the interior of the logs. In only one instance had depletion progressed sufficiently to render the timber immune from *Lyctus* infestation, and this log had an abnormally low initial starch content. In the remainder the loss of starch was considered insufficient for practical purposes. No stain or decay was observed when the logs were sawn up. Had they been kept in the round during the following summer, further depletion would probably have occurred; however, it is doubtful whether the timber would have remained without degrade.

Oak

More extensive observations were made on oak logs. In the course of visits to the yards of 10 home-grown timber merchants in the southern half of England during August and September 1938, borings were taken from 52 logs which had been stored for different periods. The intervals between felling and examination varied from 2 months to 3–4 years, but in many instances the date of felling could be ascertained only approximately. The original starch content of the logs was not known and estimation of the amount of depletion was therefore impossible. The starch content of each 0·1 inch of sapwood of every boring was recorded. Any boring which contained more than two consecutive 0·1 inch long segments of a starch grade 6, 5, 4, or 3 (see Phillips (7)) was considered to have a region of

starch rendering infestation by *Lyctus* Powder-post beetles possible. According to this very stringent classification the logs represented by the borings were grouped as in Table I.

TABLE I. *Classification of stored oak logs on the basis of the starch content of borings*

Storage period of logs: months	*Number liable to Lyctus attack*	*Number not liable to Lyctus attack*
0– 3	4	1
6– 9	8	13
12–14	1	12
18–30	0	9
36–48	1	3

The results could be interpreted only generally, since one to four borings did not form a very adequate sample of a log. Nevertheless, it seemed safe to conclude that when an oak log has been kept for 12 months or more, the sapwood will almost certainly be starch-free and therefore immune from eventual attack by Powder-post beetles. Eighteen of the logs had been peeled shortly after felling, but there was no real difference in the extent of starch depletion between the barked and unbarked stems. This observation was unexpected, for it was anticipated that removal of the bark would permit an unfavourably rapid loss of moisture. It is hardly possible that all 18 peeled logs should have originated from trees of unusually low starch content.

Confirmation of the conclusion that most oak logs would become starch-free during the first 12 months of storage was gained when borings were taken in January 1940 at the mid-points of 16 logs felled in January 1939, delivered to the laboratory in March 1939, and stored in a pile under partial cover. Examination of their starch contents showed that 11 were completely free from starch, 4 contained traces, and only 1 could be considered to contain sufficient starch to support *Lyctus* infestation.

DISCUSSION.

Storage of timber in the round entails risk of degrade from stain and decay and from insect attack, mainly by pin-hole borers. In this country, however, the risk of serious degrade is not great, except in certain parts of southern England, where oak logs are liable to severe infestation by *Platypus cylindrus*. In relation to starch depletion there is no advantage in prolonging the storage period beyond 12 months.

In commercial practice many logs felled in winter were allowed to remain unconverted in the woods or storage yards throughout the following summer or longer and during this warm period were under conditions suitable for the progress of starch depletion. Although the ends were not sealed and gradually dried out, with consequent fixation of starch in these regions, moisture was lost only slowly from the bulk of the log and the cells therein continued to live for a considerable period upon their starch reserves. Early conversion after felling, particularly if followed by kiln-drying, will lead to the death of the cells and

fixation of their starch, thus producing timber very suitable for *Lyctus* infestation. Wilson (9) wonders whether the relatively high proportion of *Lyctus*-infested wood imported from Europe, America, and Japan into the United Kingdom during the past 25 years is related to the development in those countries of methods for the rapid conversion and drying of newly felled trees; there is much to be said in favour of this view being at least a partial explanation.

It has often been observed in timber yards containing a large stock of home-grown oak logs sawn into boards and air-seasoned in stick, that the sapwood of only a small proportion of the logs was eventually infested by *Lyctus* Powder-post beetles. It may reasonably be assumed that the majority of the logs had been stored in the round before conversion long enough for the starch to be resorbed sufficiently to render the wood immune from such infestation. If this assumption be true, it is clear that starch depletion by log storage is often brought about unwittingly in the course of normal commercial practice, a point which has also been considered by Wilson (9).

In the higher temperatures of the tropics and sub-tropics storage of felled logs should result in relatively rapid resorption of the starch reserves, but such treatment will generally be impracticable, because of the almost certain spoilage of the logs by fungi and insects, particularly pinhole borers.

Finally, it must be stressed that only three species of timber have so far been investigated, and it may be that these three are especially amenable to treatment to bring about resorption of starch: some other species may not react so favourably.

SUMMARY.

Observations on short lengths of oak, ash, and walnut branchwood have shown that depletion of starch from the sapwood proceeds so long as the wood retains sufficient moisture for the cells to remain alive. During the process of depletion the risk of fungal stain or decay depends upon the species of timber and the conditions under which it is kept.

Ash logs usually possess a wide band of starch-containing tissues and cannot normally be rendered starch-free by storage under natural conditions for a year. The relatively narrow band of sapwood on oak logs, on the other hand, could generally be rendered starch-free by storage of the logs in the open or under cover for 12 months, irrespective of whether the bark was present or not.

The work described above has been carried out as part of the programme of the Forest Products Research Board and is published by permission of the Department of Scientific and Industrial Research.

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CORRELATION BETWEEN EXCENTRICITY AND SPIRAL GRAIN IN THE WOOD OF *PINUS LONGIFOLIA*

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INTRODUCTION.

IN an earlier paper (5) the writer has submitted evidence that in *Pinus longifolia* as spiral grain develops in the wood the pitch of the grain shows significant correlations with the development of excentricity in the annual increment, and, therefore, with the tracheid length and the pitch of the cellulose micelles in the tracheid wall, as both the latter had previously been shown to have a definite relation to excentricity. These observations, made at the University of Leeds, had therefore directed particular attention to the occurrence of excentricity in the annual increment as a factor possibly causally associated with spiral grain, though doubts were raised by the behaviour of normally directed horizontal branches on the trunk of trees with twisted grain.

There is considerable confusion in the literature as to the occurrence of twist on branches, which probably arises from a failure to separate two types of twist in softwood trees. In young softwoods a twist which is usually left-handed (in the sense in which the term is used of the cutting spiral on a screw) is often present, increases over some years, and then finally decreases, being covered in many trees by an outer sheath of straight-grained wood. This twist practically never shows in the 1st-year wood, is normally greater at the base of the trunk, diminishing upwards. In such trees our observations confirm the statement of Dr. M. R. Jacobs (3) made as the result of a study of young trees of *Pinus radiata*, that whilst competing branches, turning upwards in an effort to displace the leader, frequently show twist, no twist is shown in normally directed horizontal branches. On the other hand, in old, possibly over-mature, trees of *Pinus longifolia* a right-handed twist may develop in the outer rings of wood which is greater in the upper part of the bole, diminishing downwards, and this is usually associated with the presence of very irregularly developed 'contorted' branches which show a remarkably high degree of right twist (1).

These remarkable branches have not been studied, but the horizontal branches on young left-twisted trees at first sight present an exception to the general rule, stated in the first paragraph, in that here the grain is generally straight whilst there is always a marked excentricity. But in such horizontal branches in softwoods, the excentricity throughout the course of the branch is restricted to the lower side. The most superficial study of the excentricity of any annual increment in a relatively vertical softwood stem shows that there is no such fixed position of maximum growth on one side of the stem. The observations that follow show clearly that on the contrary the position of maximum growth changes its position

gradually along the length of the stem, *following a spiral course*, and such an observation is of course of the utmost significance in view of the correlation previously found in such vertical stems between occurrence of excentricity and the presence of spiral grain.

So far as is known to the writer, this definite spiral course of the excentricity in vertical softwood stems is here established for the first time. It was indicated as occurring by Champion's observations on an exceptionally strongly left-twisted chir pine (2) (loc. cit. p. 6, fig. 2), in which raised spiral ridges showed on the outer surface of the bole. Kienholz (4) noted in 'pistol-butted' trees that the maximum increment, originally present at the lower side of the convex bend higher up the trunk or branch, is found on the concave side, but no detailed study of the progressive shift in excentricity appears to have been made.

To study the progressive shift in excentricity in any one wood ring throughout a length of the axis involves a considerable amount of detailed examination; the present observations are therefore of necessity restricted to a few typical examples, taken from several seedlings, a few saplings, and one tree about 75 years old. In many cases the observations are based on measurements made on sections taken with the sliding microtome; of these micro-photographic records have been made through the courtesy of Mr. K. N. Tandam of the Forest Research Institute of Dehra Dun. These observations followed naturally on the earlier anatomical studies carried out at Leeds under the direction of Prof. J. H. Priestley, but the outbreak of war and the difficulties of communication made it doubly necessary to proceed to India and collect the specimens for observation upon the spot. Through the courtesy of the authorities of the Forest Research Institute, facilities were provided for selecting and studying specimens from Ranikhet as well as from the demonstration area at Dehra Dun, and the author acknowledges gratefully the valuable advice received from Prof. H. G. Champion on the collection of material.

In most cases specimens selected for study were stripped down to the wood surface and then a guide line drawn down one side parallel to the longitudinal axis; the specimen was then cut into numbered blocks, usually corresponding to the portions between whorls of branches; sections were then cut from the surfaces and from intermediate positions in the blocks, or the ends of the blocks planed and polished. In either case the distribution of the wood increments of each ring was then measured along eight equally spaced radii, these being serially numbered with respect to the position of the guide line. Readings of the thickness of the annual rings were made with a Leitz traversing microscope fitted with an eyepiece with cross wires and reading to 0·05 mm. Extra readings were taken where the widest portion of a ring was found to be between the original radii selected. Discs of wood cut out with a strictly transverse cut were used for the determination of the pitch of the grain, using the same Leitz microscope.

OBSERVATIONS UPON SEEDLINGS.

Many seedlings, as previous observers have noted, show a swollen carrot-like hypocotyl, and such seedlings, when the cortex is removed, frequently show

twisted grain. Whilst these seedlings appear externally of straight growth, on removal of the cortex it is usually found that the woody core shows a bend at the hypocotyl. If such seedlings are taken and a guide line drawn down the axis with a needle, it will be found on sectioning, as might be expected, that there is marked excentricity, in the second-year wood and/or in later years, with maximum radial growth and development of pressure wood on the convex (lower) side of the bend; downwards towards the root the maximum excentricity decreases and shifts position progressively, as also upwards. But the main point that emerged clearly was that in six seedlings showing right-handed twist this position of maximum thickness followed upwards shifts in an anti-clockwise direction. In other words, the position of maximum thickness follows a right-handed spiral course. Similarly seedlings with left-handed spiral grain showed a left-handed spiral course of the position of maximum thickness. A number of $4\frac{1}{2}$-year-old straight-grained seedlings which had an abnormally thick cortex at the base, on examination showed bending of the woody core at the base with marked excentricity, and pressure wood in the second ring and slight signs of it in the 3rd-year wood, but none in the 4th and 5th years' increment. Such seedling when split open showed left-handed spiral grain in the 2nd-year wood.

In all the above cases no leader replacement had occurred, but a study of a number of seedlings or undersized saplings from Ranikhet, all of coppiced origin and all showing left twist, gave results in accordance with the following example. After removing an abnormally thick cortex with straight superficial outline a dead leader was revealed with evidence that a lateral had replaced the leader. At the extreme base nine rings were visible; the second and third rings were wide and without excentricity or pressure wood. Two abnormally narrow rings then indicated the seasons when the original leader gradually failed. Then four more rings were added due to the basipetal activity of the 5-year-old replacement shoot. The inner rings showed straight grain, but the sixth and seventh rings of the basal stem, continuous with the second and third of the replacement shoot, showed both excentricity and pressure wood. The pitch of the spiral grain in the basal stump is less than in the coppiced shoot. Following the position of maximum thickness (which coincides with the position of pressure wood) upwards in the coppiced shoot, in the second ring this was at the base on the convex (lower) side of this former branch but in the third ring on the concave side. Followed upwards within 5 cm. the position of maximum thickness and of pressure wood in these two rings had completely reversed. At the base the coppiced shoot showed a high degree of twist, decreasing gradually upwards but still recognizable in the 2nd-year shoot; this high degree of twist would appear to be correlated with the rapid shift upwards in the position of maximum radial growth and of pressure wood.

OBSERVATIONS UPON SAPLINGS.

A 10-year-old sapling was very thoroughly studied by the methods described. The stem was strongly curved at the base as in a 'pistol-butted' tree and the wood showed left-handed twist. Readings of radial increments on 8 radii were

taken at 14 levels in the tree. In the following table the measurements are given with occasional values also for the inclination of the fibres.

TABLE I. *Thickness, in millimetres, of individual wood rings along different radii in a 10-year-old sapling, measured at different levels in the vertical axis*

LEVEL I. 15 cm. above soil level

	Annual ring									
Radius	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
		4·45	*4·00*							
1	0·80	3·45	3·25	6·95	5·25	2·15	3·60	5·20	4·50	1·60
2	0·75	2·90	2·00	5·85	5·25	2·75	2·80	6·00	4·20	2·55
3	0·75	2·10	1·55	5·40	5·70	2·45	3·25	5·10	3·20	2·30
4	0·75	2·05	1·20	4·80	5·10	2·00	3·35	5·75	3·75	2·00
5	0·80	2·00	1·35	4·35	5·35	1·85	3·60	6·65	4·35	*2·85*
6	0·75	2·25	1·90	5·05	6·10	*2·90*	4·40	6·85	4·90	2·45
								7·15	*5·50*	2·50
7	0·75	2·70	2·20	6·95	*7·35*	2·75	*5·20*	5·40	3·25	1·90
8	0·75	3·00	3·00	*8·20*	6·90	2·50	3·50	4·25	2·45	2·00
		4·30	3·20							

LEVEL I A. 6 cm. above I

	Annual ring									
Radius	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1	0·50	2·25	1·50	5·80	4·95	2·05	2·35	4·10	3·65	1·60
2	0·55	2·25	1·45	4·70	5·00	2·00	2·65	4·00	3·25	2·25
3	0·50	2·10	1·50	4·70	4·40	1·65	2·55	4·70	3·25	2·55
4	0·50	2·05	1·70	4·45	5·15	1·85	3·50	6·10	3·30	2·30
5	0·50	2·15	2·25	4·60	5·70	2·30	3·20	7·20	4·85	*2·65*
6	0·55	2·15	*2·70*	7·25	7·30	3·30	*5·00*	*8·30*	*6·80*	2·55
7	0·50	3·10	2·00	*9·15*	*7·75*	*3·70*	*5·00*	5·25	2·45	1·75
8	0·50	*3·20*	1·60	6·40	5·90	3·10	2·30	4·90	3·35	1·90

LEVEL II. 12 cm. above I A

	Annual ring									*Inclination of fibres*
Radius	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	
1	0·67	2·50	5·60	5·45	2·30	2·85	4·50	3·45	2·55	14°
2	0·67	2·55	5·50	6·10	2·50	3·00	5·30	3·60	2·75	12°
3	0·65	2·55	5·40	6·25	2·75	3·45	7·00	4·40	2·60	12°
4	0·70	2·50	6·25	6·30	2·50	3·45	*7·70*	4·85	*3·15*	10·5°
							7·60	*6·40*	2·60	
5	0·67	2·60	6·95	6·20	*2·80*	*5·30*	7·35	5·40	2·40	10·5°
6	0·67	2·60	*7·15*	*6·40*	2·50	4·90	4·60	2·40	2·05	13°
7	0·65	2·50	6·85	5·45	2·50	3·65	4·50	3·60	1·70	16°
8	0·70	*2·65*	6·55	5·35	2·20	3·20	4·10	2·80	1·55	16°

LEVEL II A. 23 cm. above II, stem 8 years old, but 2 outer rings removed on lathe; inclination of fibres measured for each ring.

	Annual ring											
	1		*2*		*3*		*4*		*5*		*6*	
Radius	*Thick.*	*Incl.*	*Thick.*	*Incl.*	*Thick.*	*Incl.*	*Thick.*	*Incl.*	*Thick.*	*Incl.*	*Thick.*	*Incl.*
1	1·48	0°	5·00	6·5°	5·85	10·3°	2·20	12·5°	3·40	12·3°	6·15	16·3°
2	1·45	0°	5·65	5·5°	5·35	10·5°	2·55	10°	3·70	12·3°	6·35	13·1°
3	1·50	0°	5·50	5°	5·35	8°	3·10	9°	4·95	9·3°	7·60	10°
									5·50		5·15	
4	1·48	0°	5·90	5°	6·25	7·16°	4·00	9·3°	4·70	8·6°	4·55	11°
										Incomplete		
5	1·48	0°	6·00	5°	5·75	7·6°	3·50	9·16°	3·95	11·6°	4·90	12°
6	1·45	0°	5·30	5°	6·45	7°	3·35	10·1°	3·60	14°	4·30	14·1°
7	1·50	0°	5·15	6°	6·35	7·3°	2·55	10°	2·95	14°	4·70	15·1°
8	1·48	0°	5·05	7°	5·75	11°	2·45	12°	2·90	14·3°	5·20	16·2°

LEVEL III. 15 cm. above II A

	Annual ring								
Radius	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*Inclination*
1	1·20	4·35	5·55	2·60	3·75	6·25	4·45	1·85	15·6°
2	1·15	4·55	5·95	3·10	4·15	7·10	5·15	3·60	11·1°
					5·00	7·05	6·15	3·75	10°
3	1·25	4·10	6·05	4·20	4·85	6·90	6·10	3·10	10·3°
4	1·25	4·35	6·05	3·05	4·50	5·05	4·00	2·80	11°
5	1·20	4·50	6·05	3·40	3·20	4·20	3·75	2·05	13·7°
6	1·15	4·65	4·75	3·70	3·95	4·65	2·95	2·05	15°
7	1·25	4·50	5·50	2·25	3·20	5·55	3·50	2·00	15·8°
8	1·25	4·55	5·30	2·25	3·35	5·50	3·45	2·15	16°

LEVEL IV. 30·5 cm. above III

	Annual ring							
Radius	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*Inclination*
1	1·85	3·50	2·70	3·80	6·05	5·55	4·35	16°
2	1·77	3·70	2·75	4·85	7·40	6·50	3·75	12°
3	1·80	3·70	2·95	4·90	7·00	5·85	3·60	13·8°
4	1·85	3·80	3·00	4·30	6·35	5·35	3·90	16·16°
5	1·85	3·70	2·80	4·05	6·35	5·10	2·85	16·5°
6	1·77	3·60	2·40	3·90	5·85	5·10	3·20	17°
7	1·80	3·55	2·40	3·30	4·85	5·10	2·85	17·5°
8	1·85	3·60	2·35	3·50	4·70	4·90	3·05	17°

Level V. 33·5 cm. above IV

Radius	Annual ring 1	2	3	4	5	6	Inclination
1	1·00	2·00	4·15	7·20	7·45	5·35	15·6°
2	0·95	2·10	4·45	7·05	6·65	3·95	15·5°
3	1·00	1·90	4·40	6·55	6·50	3·85	17·3°
4	1·00	1·90	4·60	7·70	5·30	3·70	18°
5	1·00	1·90	4·85	6·95	5·70	3·55	17°
6	0·95	2·15	4·40	6·40	6·05	4·05	16°
7	1·00	2·05	4·20	6·40	5·75	4·15	15°
8	1·00	2·00	4·15	6·20	6·25	4·80	16·5°

Level VI. 16·5 cm. above V

Radius	Annual ring 1	2	3	4	5	Inclination
1	1·32	3·40	7·50	7·70	4·35	13·5°
2	1·30	3·35	7·70	6·15	5·25	12°
3	1·32	3·35	7·10	7·00	4·05	12·7°
4	1·32	3·35	7·05	7·15	4·65	14·3°
5	1·32	3·40	7·35	6·85	4·70	13°
6	1·30	3·70	7·10	7·10	4·05	14°
7	1·32	3·65	7·25	6·95	4·40	14°
8	1·32	3·50	7·00	7·70	4·55	13°

Level VII. 29 cm. above VI

Radius	Annual ring 1	2	3	4	Inclination
1	1·82	5·40	7·60	5·95	10·16°
2	1·87	5·60	7·65	5·15	10·3°
3	1·80	5·85	7·65	5·15	11°
4	1·87	5·80	8·00	5·20	12°
5	1·82	6·60	7·90	4·95	12·5°
6	1·87	5·60	7·95	5·05	12°
7	1·80	5·35	7·50	4·75	12°
8	1·87	5·50	7·00	5·75	11·3°

LEVEL VIII. 40 cm. above VII—in branch which has replaced leader, 3 years old

	Annual ring		
Radius	*1*	*2*	*3*
1	2·05	7·85	6·00
2	2·00	8·95	7·15
		9·15	
3	2·05	8·60	7·10
4	2·07	7·80	7·45
			7·75
5	2·05	7·85	6·80
6	2·00	7·85	5·65
7	2·05	7·35	5·80
8	2·07	7·35	5·65

LEVEL VIII A. 9 cm. above VIII

	Annual ring		
Radius	*1*	*2*	*3*
1	2·20	6·65	6·30
2	2·13	6·75	7·25
3	2·15	6·80	6·85
4	2·17	6·55	6·75
5	2·20	6·75	6·80
6	2·13	6·75	6·25
7	2·15	6·75	6·50
8	2·17	6·80	6·30

LEVEL VIII B. 50 cm. above VIII A

	Annual ring			
Radius	*1*	*2*	*3*	*Inclination*
1	1·82	3·85	6·50	7·16°
2	1·87	4·10	5·85	7·16°
3	1·87	4·05	6·00	7·5°
4	1·87	4·05	6·35	8·6°
5	1·82	4·10	6·15	7·5°
6	1·87	3·95	6·25	8·16°
7	1·87	4·00	6·35	7·5°
8	1·87	3·90	6·40	7°

LEVEL IX. 25 cm. above VIII B

	Annual ring		
Radius	*1*	*2*	*Inclination*
1	3·52	4·55	7°
2	3·47	4·60	6·5°
3	3·42	4·75	6·5°
4	3·47	4·55	7°
5	3·52	4·60	6·5°
6	3·47	4·60	6·7°
7	3·42	4·55	6·8°
8	3·47	4·55	7°

LEVEL IX A. 36 cm. above IX

	Annual ring		
Radius	*1*	*2*	*Inclination*
1	2·32	3·35	5°
2	2·20	3·25	5°
3	2·25	3·30	5°
4	2·20	3·25	5°
5	2·32	3·25	5°
6	2·20	3·35	5°
7	2·25	3·45	5·3°
8	2·20	3·35	5°

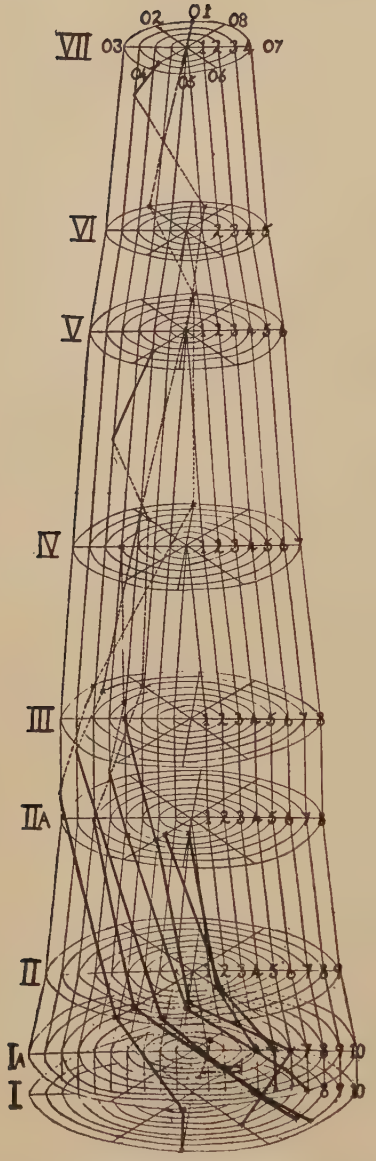

FIG. 1. Diagram showing the shift in the position of maximum thickness in the successive radial increments in a sapling of *Pinus longifolia*. At each level the point of maximum thickness is marked in each ring; at the front of the figure points in the same layer, at different levels, are joined by continuous lines, points on the back of each wood cylinder by dotted lines.

In each vertical column of figures for radial increment the position of maximum thickness is indicated by italicizing the figure; when the maximum thickness occurs between the radii selected, additional measurements are sometimes recorded appearing as interpolated entries in the vertical column. From these data Fig. 1 has been constructed in which the vertical distances between the successive levels are to scale and at each level, in each ring present, the position of maximum thickness is indicated and joined by a line with the position in the same ring at other levels.

Where the lines join points on radii facing the front the lines are continuous, where they move to points on radii at the back they are dotted, and it is at once strikingly apparent how positions of maximum excentricity in all rings, with very few exceptions, as they are followed upwards move to the left on the front of the figure, to the right at the back. In other words, in this tree with left-handed spiral grain the position of maximum excentricity in a whole series of cylinders of wood put on as annual increments is also found to follow a left-handed spiral course up the tree. Exceptions can be found to this generalization (ring 6, levels I and I A; ring 5/4, IV to V; ring 4/3, VI to VII), but the general trend upwards in a left-handed spiral is quite unmistakable. Another point of interest, also frequently noted in these observations of the position of maximum excentricity, is that in a series of rings at the same level this position also shifts; thus at level I the position of maximum increment is shifting from radii on the back of the figure on the inner rings to radii in the front in later rings, and usually it appears to be shifting in a clockwise direction. At level I this holds for rings 2 to 6 and 9 to 10, 7 is a marked exception, and between 8 and 9 there is practically no shift. In view of the similar general left-hand spiral shift shown in all rings when the excentricity is

followed upwards, naturally the same tendency shows at all levels above I, but with some fluctuations as the rate of shift along the vertical axis may not be the same in each ring.

From the data recorded in these tables one may reasonably conclude that the bend at the base of the stem is associated with marked excentricity and that this excentricity in successive radial increments has travelled up the stem in a left-handed spiral, growing gradually less upwards as it is followed in any cylinder of radial increment. This latter point may be rather obscured by the fact that in the later increments the ring width increases upwards for some distance. Relative excentricity with varying radial increment has been expressed as a ratio of the maximum over average thickness for that level in the ring, the value for average increment being expressed as unity. The figures thus obtained are given in Table II and have been plotted in Fig. 3 for the last six radial increments added. It will be seen that there is some irregularity in the position at which the maximum width is achieved (Fig. 2), but on the whole in later rings the position of maximum width tends to move to higher levels; more strikingly still, the rapid fall in thickness of the ring which occurs in every new sheath of wood when followed upwards is found to occur at a higher level quite regularly in each successive layer of wood. On the other hand, the ratio of maximum to average width, i.e. the degree of excentricity, seems to lag very much behind in any tendency it may have to move upwards. Indeed until the last increment is reached the maximum excentricity is invariably shown, in these last six increments, at level I A.

TABLE II. *Figures for Maximum/Average width, when average*=1

	Ring number									
Level	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*
I	1·27	1·37	1·21	1·44	1·19	1·26	1·38	1·70	1·52	1·05
I A	1·23	1·76	1·49	1·51	1·49	1·34	1·55	1·47	1·33	1·08
II	1·33	1·56	1·32	1·43	1·12	1·08	1·14	1·04	1·05	
II A	..	..	1·40	1·39	1·35	1·09	1·10	1·01		
III	1·45	1·40	1·22	1·25	1·37	1·07	1·05	1·03		
IV	1·26	1·20	1·22	1·20	1·12	1·04	1·02			
V	1·28	1·20	1·13	1·10	1·07	1·01				
VI	1·17	1·10	1·04	1·07	1·01					
VII	1·14	1·05	1·16	1·02						
VIII	1·18	1·13	1·02							
VIII A	1·09	1·01	1·02							
VIII B	1·04	1·02	1·01							
IX	1·03	1·01								
IX A	1·04	1·04								

There may, however, be a slight tendency for the degree of excentricity, even if then relatively less in degree, gradually to move upwards in the tree as the position of maximum thickness so moves with increasing age. Thus, in the increments not plotted on the curve (see Table II), in the 2nd and 3rd year of growth, maximum excentricity (relatively great in extent) appears at level I,

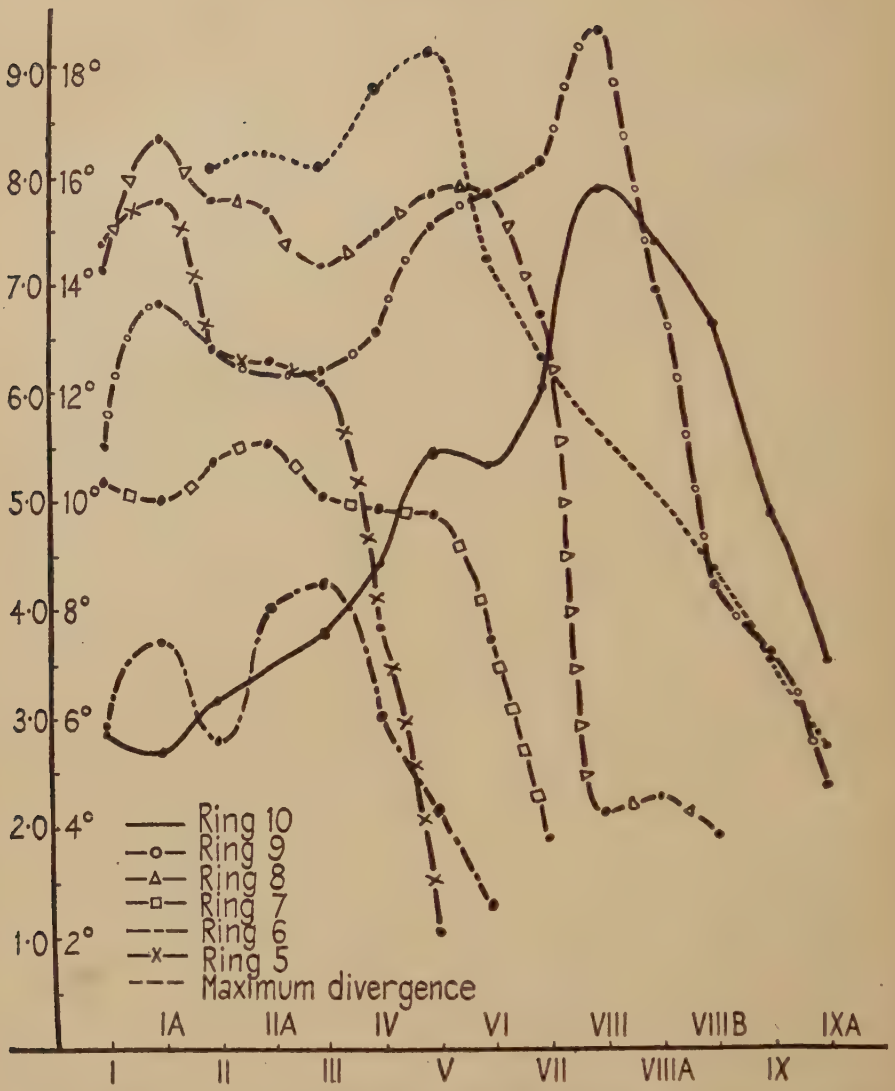

Fig. 2. Maximum width in radial increments of years 5–10, compared with maximum divergence (from the vertical) on wood surface (dotted line), at different levels.

shifting in the 4th year to level I A where it remains until the 10th year, when it moves to level III. Further studies will be needed to test this possibility of an upward shift of the position of maximum excentricity; the present data, as shown by Fig. 3, firmly substantiate the fact that the excentricity in all increments diminishes progressively upwards and with this diminution in excentricity also falls the degree of twist.

Another sapling examined permitted thorough study of the influence of leader replacement upon excentricity and twist. A sapling about 20 feet in height, when

skinned and prepared for measurement with the usual vertical guide line on the wood surface, showed leader replacement at a height of some 7 feet above the ground; this replacement leader showed some 7 years' growth, whilst a block taken near the base of the sapling showed 12 years' growth. In the lowest block the surface wood shows straight grain, though the outer 7 rings, connected with

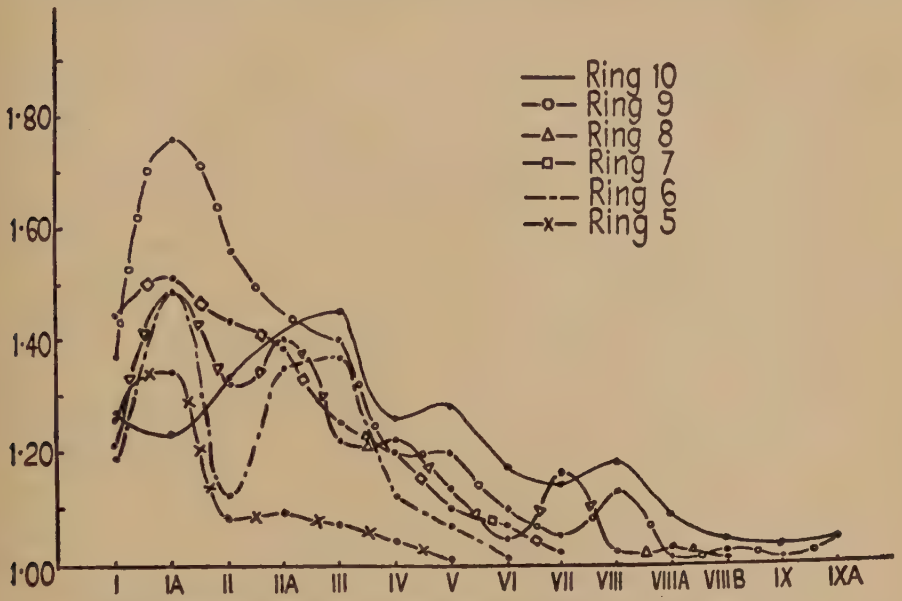

FIG. 3. Relative excentricity in increments of years 5–10, at different levels.

the wood of the leader replacing branch, are narrow and slightly excentric. None of the rings from the circumference to the centre, in this basal block, shows any spiral grain when exposed by tangential cuts.

Blocks were taken from each year's growth above the basal 'internode', and only in the third block upwards is there a trace of spiral (left) grain on the surface—this block shows 10 rings and the outer 7 show a little excentricity and considerable production of summer wood.

The next 'internode' shows definite left twist and the outer 7 rings are definitely excentric with a considerable proportion of pressure wood in the 6 outer rings. From the leader replacing branch down to this point, the position of maximum thickness has undergone downwards an anticlockwise shift through about 90°. Slight spiral grain made its appearance towards the periphery of the third ring, increasing in pitch up till the seventh ring, diminishing slightly in the eighth and ninth (last).

A little below the leader replacing branch a section showed 9 rings of wood, of which the 7 outer are excentric with pressure wood directed towards the originally lower side of the branch.

The surface of the wood below the site of the leader replacing branch showed definite left twist which commenced in the middle of the second ring; at this

point on the main stem 8 rings were visible with rings 2–8 excentric and the widest portion facing the insertion of the leader replacing branch. A section 8 inches above this showed 8 rings with no excentricity and pressure wood in the second ring, but the widest zone of rings 3–8 had shifted through about one-eighth of the circumference in a clockwise direction. Followed upwards in what is now the axis formed by the leader replacing branch, the outer rings continued excentric with a continued clockwise shift of the position of maximum thickness. When the 6-year-old 'internode' is reached the position of maximum thickness in the 4 outer rings (3–6) has moved through 180°, and this sharply spiral course of the position of maximum thickness is associated with an increasing inclination of the grain on the surface of the wood. Above this level, however, the twist of the grain begins to diminish, though in the 5-year-old axis the 3 outer rings are still excentric. Between the 6th-year and 5th-year 'internode' the position of maximum thickness and of pressure wood twists in a clockwise spiral almost completely round the axis in a distance of 2 feet. Upwards both excentricity and pressure wood and spiral grain gradually diminish, excentricity and pressure wood are not recognizable even in the 3rd-year shoot, left twist, though slight, persists even into the 2nd-year shoot. In this sapling, then, there is evidence that excentricity, present as usual at the base of a horizontal branch, when that branch turned upwards to replace the main shoot, was propagated downwards in the main axis and upwards from the base of the replacement leader, in each case the position of maximum thickness following a left-hand spiral course, and being associated with development of left-twisted grain.

From another slender sapling from Ranikhet about 8 feet high, showing slight right twist, a 3-foot length was cut out about 3½ feet above ground level. Transverse sections were cut at five different levels in this piece, about 7–8 cm. apart. The base of this piece showed about 20 annual rings; microtome sections showed 5 rings, or groups of rings, with marked excentricity and usually with pressure wood in the region of maximum thickness. With the exception of the second ring from the outside, where the position of maximum thickness shows a slight clockwise shift upwards, all other regions of maximum thickness showed a gradual anticlockwise shift when followed upwards. The shift is gradual and over the (3-foot) length studied does not exceed a quarter of the periphery of the stem in any case; with this may be associated the low pitch of right twist which at the base is not greater than 5° on the widest side of the ring, rising to 7°–10° on the other side of the stem.

OBSERVATIONS ON A TREE.

Observations of this type on well-grown trees are obviously difficult, but the following facts were noted in the case of a large tree at Ranikhet, about 75 years old and 50 feet high with a comparatively straight, though slender, shaft, and in which the wood, at breast height, showed more than 45° left twist.

A piece was cut out of the trunk about 3½ feet long, at a height of some 25 feet from the ground. This was cut into five lengths and the surfaces planed and polished. Forty rings were visible at the base, and these rings were studied in

groups of 10 by marking carefully each tenth ring with ink; at higher levels the same groups were marked, making allowance for the gradual disappearance of the innermost rings. The progressive changes in excentricity, in these groups, then showed themselves clearly, when the surfaces were divided into the usual 8 octant sectors always with reference to one vertical guide line drawn on the trunk before it was cut up. Followed upwards, in a space of some 11 inches the position of maximum thickness of the innermost group of rings moved through 3 octants in a clockwise direction, of the next group through 2 octants, of the next through 5—more than half-way round the stem, so that intermediate surfaces had to be studied to confirm that the shift was occurring in a clockwise direction; the last group of rings also showed a shift of excentricity clockwise through 2 octants.

Thus in this case of a trunk with markedly spiral grain, the position of maximum excentricity in all groups of rings was showing a rapid shift along a left-hand spiral course. A study of the twist in the grain in rings of different age showed it as about 5° at the 3rd ring, 18°–20° at the 10th, 30° at the 20th, 40° at the 30th, and nearly 30° on the surface. It was also clearly demonstrable in this tree that the pitch in the inner elements of the phloem was identical with that in the outermost rings of the xylem, so that there can be no doubt that the same pitch is present in the cells of the cambium, and thus found in the secondary tissues cut off from the cambium during radial growth.

SUMMARY AND CONCLUSIONS.

The evidence presented from the study of seedlings, saplings, and one tree of *Pinus longifolia* supports strongly the existence of a correlation, as previously suggested, between the presence of excentricity in the annual increment of wood and the occurrence of spiral grain.

In every case also, when excentricity has been seen in the shaft of the erect shoot, the position of maximum thickness has been found to follow a spiral course in the axis. Furthermore, if this is a left-handed spiral, as is usually the case, then the wood has shown left-handed spiral grain; when the position of maximum thickness follows a right-handed spiral course the spiral grain is right-handed. The degree of twist in the grain also shows correlation with the pitch of the spiral course followed by the position of maximum excentricity.

A connexion between excentricity and spiral grain thus seems well established; attention is thus drawn to the factors at work in producing excentricity in the vertical shaft of the tree. In numerous seedlings this can be associated with a kink in the woody axis at ground level which results in excentricity and spiral grain in the inner (second and subsequent) rings of wood which may be overlaid in later years by symmetric increments of straight-grained wood, but for various reasons—as in the 'pistol-butted' trees growing on steep slopes—excentricity and spiral grain may persist over many growing seasons.

Leader replacement by lateral branches is a frequent cause of excentricity; often appearing first at higher levels, it is propagated both upwards and downwards along the axis, the position of maximum thickness then follows in both directions a spiral course and is associated with the development of spiral grain.

In all the cases studied excentricity and spiral grain have been introduced early in the life of the plant. Usually the course of the position of maximum thickness is a left-handed spiral, as also is the pitch of the spiral grain associated with it; both are occasionally right-handed, but in either case both excentricity and spiral grain have a tendency to disappear in later years when the factors originally at work producing excentricity seem less in evidence; thus both excentricity and spiral grain diminish as they are followed upwards in the trunk and never show in the 1st-year shoot. These observations have therefore, at the moment, no clear connexion with another phenomenon, the marked twist in grain, apparently invariably right-handed, shown in older and possibly over-mature trees of *Pinus longifolia*, which is more marked in the crown of the tree and diminishes towards the base and which is often associated with the presence of irregularly grown, 'contorted' branches which may show an extreme degree of right twist.

ABSTRACT.

P. Misra. 'Correlation between excentricity and spiral grain in the wood of *Pinus longifolia*.'

The connexion between excentricity and spiral grain has been studied in the wood of *Pinus longifolia* in seedlings, saplings, and the adult tree. When excentricity is found in the vertical axis it is frequently present as the result either of a bend in the base of the axis or as the result of the replacement of the leader by a lateral. In either case the position of maximum thickness in any excentric ring, if traced along the length of the axis, is found to follow a spiral course; the degree of excentricity diminishes upwards and is never strongly developed in the 1st-year wood. Similarly the spiral grain of the wood diminishes upwards in relatively young trees, never appearing in the 1st-year wood. It is found that if the course of the spiral followed by the position of maximum thickness in the tree is left-handed, then the wood shows left-handed spiral grain; if the course of the spiral is right-handed, then the grain also has a right-handed twist.

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(1) Canning, F.: *Indian Forester*, xli, 112, 1915.
(2) Champion, H. G.: *Indian Forest Records*, xi, 1, 1925.
(3) Jacobs, M. R.: Leaflet No. 50, Commonwealth Forestry Bureau.
(4) Kienholz, Raymond: *American Journ. of Bot.* xvii, 739, 1930.
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SOCIETY'S AND OTHER NEWS

FINANCES

At a Council Meeting held in Edinburgh on 13 June 1943 the audited accounts for 1942 were adopted, the credit balances being: General Fund, Capital £383. 17*s*. 9*d*., Revenue £193. 10*s*. 5*d*.; Medal Fund £22. 7*s*. 2*d*.; Excursion Fund £22. 1*s*. 4*d*. The uninvested portion of the capital balance, the bulk of the revenue balance, and the whole of the Medal and Excursion Fund balances were in Edinburgh Savings Bank and thus on loan to the Treasury.

MEMBERSHIP

A considerable number of members who had allowed their subscriptions to fall into arrear during the early years of the war have now paid these and been reinstated. But there are still several who have not responded to the Treasurer's reminders. The membership at the end of 1942 was 142, being 45 below the peak reached in 1939, but the figure at the end of this year should be decidedly better.

TREE MEASUREMENTS

Mr. Reginald Davey contributes the following note (see *Forestry*, XVI, p. 56):

The Scheme for Pooling Tree Measurements has now entered upon its second year, with 32 collaborators (23 England, 7 Scotland, 1 Wales, and 1 Northern Ireland), including three peers of the Realm and the President of the Chartered Surveyors Institution. Data so far received total:

	Hardwoods	*Conifers*
England	386	443
Scotland	60	207
	446	650

Additional support is desired to extend this work, enabling (*a*) completion of taper tables for hardwoods as well as conifers; and (*b*) comparison of stem form in different parts of the country.

The above data give a preliminary indication of the accuracy of the taper tables published in *Measurement of Trees*. Comparison was made with the mean tapers of the 28 conifer and 28 hardwood stands providing the data. It was found that the conifer taper tables gave the mean tapers of all the stands within 11 per cent. (in terms of volume), 26 within 10 per cent., and 21 within 5 per cent. A preliminary hardwood taper table promised even better results, namely all within 10 per cent., 26 within 8 per cent. and 20 within 4 per cent.

WILD-LIFE AUTHORITY FOR GREAT BRITAIN

THE body known as the Universities Federation of Animal Welfare proposes that a Wild-Life Authority should be set up in this country with the following objectives:

1. To make available a body of sound ecological knowledge as a basis for the regulation of fauna and flora.
2. To promote the conservation of rare, beneficial, and aesthetically valuable British species in collaboration with organizations already existing for this purpose.
3. To promote the regulation of harmful species on a quantitative basis.
4. To develop and bring into use humane methods of fauna control in collaboration with appropriate humanitarian organizations.

Those interested can obtain particulars from the Honorary Secretary, 284 Regents Park Road, Finchley, London, N. 3.

NOTICES

Decimal Hoppus Tables. By S. E. WILSON. Scientific Computing Service Ltd., London, 1941. Price 6*s*.

Decimal Scantling Measurer and Petrograd Standard Calculator. By S. E. WILSON. The Lumberbook Co., Clevedon, Somerset, 1943.

These two books, giving the relevant statistics on a decimal basis, will be of great utility and the author and publishers are to be congratulated on making them available.

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